APPLIED MECHANICS
Reviews

A CRITICAL REVIEW OF THE WORLD LITERATURE IN APPLIED MECHANICS AND RELATED ENGINEERING SCIENCE

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APPLIED MECHANICS *Reviews*

RECENT ADVANCES IN THEORIES OF CREEP OF ENGINEERING MATERIALS

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IF AN engineering structure is subject to creep, any state of stress will correspond to a state of flow in the solid material, in practical cases so slow that inertia effects may be neglected. The strain velocity, usually termed creep rate, is, in general, a function of stress, total deformation, and time as well as of the time history of stress and strain (aftereffects). It is the objective of this paper to follow the development of laws governing this relationship and, in particular, such theories as allow conclusions from laboratory tests on materials for full-size engineering structures.

If, from a laboratory test at constant uniaxial tension and constant temperature, the total strain ϵ is plotted against time t, a creep curve will be obtained (see Fig. 1) where the steeper curves correspond to higher values of stress and/or temperature. For small values of t, the creep rate $d\epsilon/dt$ decreases during the stage of "primary creep" and approaches a constant value v during the stage of "secondary creep." Later on, further changes in the creep rate and/or fracture might occur. Neither of these latter phenomena has given rise to engineering theories so far and both will be left out of consideration in the sequel. The period of primary creep may have longer or shorter duration depending on stress, temperature, and type of material.

The first attempts toward analytical treatment of the material properties disclosed by Fig. 1 neglected the influence of primary

Fig. 1 Creep curves for constant stress and temperature ($\sigma_1 < \sigma_2 < \sigma_3$)

creep and were merely concerned with relationships between the rate v of secondary creep and the constant stress σ; e.g., in the form given by F. Norton

$$v = k\sigma^n \qquad [a]$$

where k and n are material constants depending on temperature.

Relationships of the type of Equation [a], derived from tests at constant uniaxial stress, were then generalized to time-dependent stress merely by putting

$$d\epsilon/dt = k\sigma^n \qquad [b]$$

Taking into account the facts that only elastic volume changes will occur during creep and that the plastic strain tensor in creep ϵ_{ik} will be uninfluenced by hydrostatic pressure, generalization of [b] to three dimensions yields

$$d\epsilon_{ik}/dt = 3/2 \cdot k\sigma_e^{n-1}s_{ik} \qquad [c]$$

where s_{ik} is the stress deviation tensor and σ_e the "effective stress," defined through

$$\sigma_e^2 = 3/2 \sum_{i,k=1}^{3} s_{ik}^2$$

The development of theories of this kind up to 1951 was reviewed by J. Marin (1).[1] A comparatively simple theory for buckling of columns in creep based upon Equation [b] has recently been given by N. J. Hoff (2). It shows the remarkable result that a column of idealized H-section of small initial curvature will buckle or rather obtain finite deflections, for any axial load however small, after a finite time.

For modern creep-resistant alloys, e.g., such as are used in gas turbines and jet engines, the primary stage of creep may prevail during most of the service period, and improvements in the theoretical treatment become necessary. As in the afore-mentioned theories, finite deformations may be neglected. Then, the total effective strain should not exceed the order of 10^{-2}, which will suffice for many important applications. The stresses may also still be referred to the undeformed body, an assumption which greatly simplifies the mathematical treatment.

One such purely phenomenological theory could be traced back to A. Nadai's research group (3) and has been further developed by I. Roberts (4) and generalized to three-dimensional stress systems only recently by R. W. Bailey (5). This theory takes as point of departure an equation of the type

$$d\epsilon/dt = K\sigma^r\epsilon^{-q} \qquad [d]$$

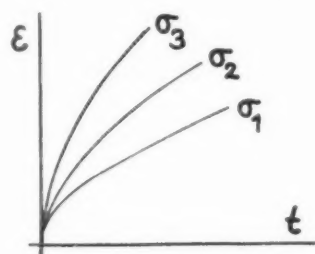[1] Numbers in parentheses indicate References at end of paper.

with K, p, and q constant. For the conditions of a creep test with σ constant, Equation [d] delivers, integrated

$$\epsilon = k\sigma^n t^{1/(q+1)} \qquad [e]$$

with

$$k = K^{1/(q+1)} \cdot (q+1)^{1/(q+1)}, \qquad n = p/(q+1)$$

whereas [b] would give

$$\epsilon = k\sigma^n t \qquad [f]$$

Equation [e] has a greater adaptability to creep curves than [f]. Equation [d], different from other generalizations of Equation [e], seems to be able to account also for time-dependent stresses such as occur, e.g., in tests with intermittently constant stresses of different levels or in relaxation tests (4). It could therefore be stated that Equation [d] in a certain sense forms the only acceptable generalization of Equation [e] (with constants determined from creep curves) to time-dependent stress. Hence other attempts (6) to generalize Equation [e] in the form

$$d\epsilon/dt = k\sigma^n f(t)$$

where $f(t)$ is some function of the time, are not free from objection (4).

Equation [d] neglects the effects of stress recovery (aftereffects) and quite correctly so for a number of stable materials of the type of structural steels, light alloys, etc. Its drawback is its complicated nature, which so far has admitted of but few applications. Its extension to buckling problems by C. Libove leads to very lengthy calculations (7, 8). Still, Libove's analysis, contrary to Hoff's (2), may not easily be carried beyond the first deflection approximation in the form of a simple sine wave. A crude model, already showing some of the characteristics of column buckling in creep, had been developed somewhat earlier by F. R. Shanley (9).

Looking for an alternative theory, it may be wise to turn to the findings of physicists within this domain. As will then soon be revealed by two publications (10, 11), picked at random, the literature on the subject is becoming very comprehensive indeed. This fact alone accounts for the present review being very far from complete. The bibliography (10), covering creep of metals only, for two recent years contains 160 entries. The picture offered by theoretical physicists, based on the conception of dislocations (11), seems to be but in its infancy and is still far too complicated for engineering applications.

In order to obtain something manageable, it is necessary to make compromises and try to make certain simplifications. It must always be kept in mind that the creep properties of engineering materials are but roughly known. This may depend partly on measuring difficulties derived from the high values of n and strong temperature dependence of k in Equation [a], partly (and perhaps most seriously) on large influence on the creep properties by even small differences in chemical composition or in the manufacturing process, including heat treatment.

It was established long ago by H. F. Moore and co-workers (12), experimenting with lead, that the same amount of creep could be obtained alternatively after a short time with high stress or after a long time with lower stress. In the former case, the deformation consisted for the most part of slip motion within the metal grains, and, in the latter case, the deformation was located principally in the neighborhood of the grain boundaries, the grains rotating individually more or less like the behavior of the particles of a viscous liquid.

Metal slip is known to be an irreversible process. This is the reason why the "incremental" theories of ordinary plasticity should be preferred to the so-called "finite" theories. For many metals, monotonic slip deformation corresponding to uniaxial

stress σ could be expressed in exponential form $= k_0 \sigma^{n_0}/n_0$, where k_0 and n_0 are constants. Assuming that the creep rate be composed of the time derivative of such a slip term and, in addition, a term corresponding to viscous creep according to [b], one would get (13, 14)

$$d\epsilon/dt = k_0 \sigma^{n_0-1} \cdot d\sigma/dt + k\sigma^n \qquad [g]$$

In the case of σ constant this equation could be integrated to

$$\epsilon = \epsilon^{(0)} + k\sigma^n \cdot t \qquad [h]$$

which is capable of representing creep curves very accurately in the secondary stage but fails to give an accurate representation in the primary stage (deviations in the hatched area of Fig. 2). The
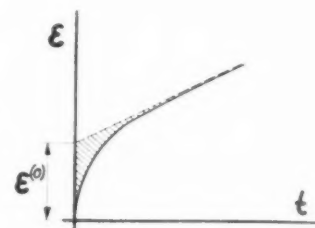
Fig. 2 Creep curve, simplified according to theory, Equation [h]

intercept $\epsilon^{(0)}$ of Fig. 2 will depend on σ (14). It could be said that Equation [g] takes account of primary creep as an integral effect without giving details. As the first term on the right side of [g] denotes an irreversible effect, it should be retained only if $d\epsilon/dt$ maintains its sign throughout the deformation. If $d\epsilon/dt$ becomes zero or changes sign, the slip term in [g] should be dropped, thus accounting for the essentially "finite" character of this term.

Equation [g] neglects aftereffects as well as deformations of the order of elastic strain. For ordinary structural steels and light alloys it will be applicable to real structures in the region $10^{-4} < \epsilon < 10^{-2}$ of deformations. Equation [g] is not capable of representing relaxation phenomena, where creep strains of the order of elastic strains have to be considered, but it satisfies Roberts' requirements (4) of representing tests with intermittent, different constant stress levels, mentioned above. It has been applied to the problem of column buckling (13) and shows an influence of primary creep, giving a shorter time for the buckling process than Hoff's corresponding formula (2).

Equation [g] has been generalized to three dimensions (13, 14, 15). The condition that $d\epsilon/dt$ shall maintain its sign then takes the form: the plastic work, i.e., the scalar product of stress deviation and creep rate tensor, shall maintain its sign during deformation in order that the slip term shall be retained. The slip term having essentially "finite" character, the theory may not be expected to represent rapid changes in the ratios of the principal stresses and/or changes in the principal directions of the state of stress. A theory of this kind could be used as a foundation for the mechanics of engineering processes such as forging, hot-rolling, wire drawing, etc. Still, the mathematical difficulties will be considerable. So far, the theory has been applied only to the formation of residual stresses due to welding (16).

Equations [d] and [g] are typical work-hardening theories, where $d\epsilon/dt$ may take any value, depending on the stress and its time derivative. It may, of course, be argued that the theories after all will not be able to account for the behavior of real solids at too high creep rates. As an alternative to Equation [g] for moderate creep rates, admitting of simpler mathematical treatment and more closely connected with von Mises' theory of ordinary plasticity, a third theory has been proposed (13, 14). Equation [b] is then supposed to hold for moderate stress values σ; but if σ reaches the yield stress σ_y, it remains at that value and $d\epsilon/dt$ becomes undetermined. Generalization to three dimensions

analogous to von Mises' theory of plasticity. Thus modified, the theory treats primary creep as an integral effect, caused by ordinary plasticity. The theory has been applied to creep in rotating disks (14). The creep rate in those parts, near the center hole of the disk, where the yield limit is reached, will be determined by the continuity of the flow and the creep resistance in the outer parts of the disk, where Equation [c] holds true.

A slightly more general theory, introducing a yield limit and also work hardening and viscous creep, has been studied by A. Wang and W. Prager (17), who give extremum principles for the solving of boundary-value problems of a solid body subject to creep.

If aftereffects must be taken care of, which may be necessary, e.g., for certain high polymers and artificial resins, this may be done according to Y. N. Rabotnov (18), who has introduced the Volterra hereditary function into the mechanics of creep, also for three dimensions.

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Charlton, T. M., Model analysis of structures, New York, John Wiley & Sons, Inc., 1954, xii + 142 pp., $5.

Federhofer, K., Aufgaben aus der Hydromechanik, Wien, Springer-Verlag. 1954, v + 221 pp., 235 figs. $5.70.

Fox, L., A short table for Bessel functions of integer orders and large arguments (Royal Soc. Shorter Math. Tables no. 3), New York, Cambridge University Press, 1954, 28 pp. $1.25.

Hewes, L. I., and Oglesby, C. H., Highway engineering, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1954, xi + 628 pp. $8.

Kiefer, P. J., Kinney, G. F., and Stuart, M. C., Principles of engineering thermodynamics, 2nd ed., New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1954, xv + 539 pp. $7.75.

Lessells, J. M., Strength and resistance of metals, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1954, xiv + 450 pp. $10.

McAdams, W. H., Heat transmission, 3rd ed., New York, McGraw-Hill Book Co., Inc., 1954, xiv + 532 pp. $8.50.

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Weber, E., Linear transient analysis. Vol. I. Lumped-parameter two-terminal networks, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1954, xiv + 348 pp. $7.50.

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Letters to the Editor

3780. Re AMR 7, Rev. 877, March 1954: A. Miele, General solutions of optimum problems in nonstationary flight.

In connection with the above review, the following comments are in order:

1 Reviewer does not describe the method actually used by author in his paper. Reviewer rather describes some other paper, probably the imaginary paper he would have written, should he have investigated the same problem.

2 In all the review there is no clear-cut distinction made between reviewer's and author's opinion. Remarks such as "Reviewer believes..." are missing despite the fact that the review in question is actually only a summary of the opinions of the reviewer.

3 Reviewer states: "In general, these conditions are not satisfied and this problem, which author calls minimum absolute problem, has no indirect solution, even if he mentions it without giving the effective construction of the $V(Z)$ optimal end arcs through $(V_1 Z_1)$, $(V_2 Z_2)$ intersecting $(V, Z) = 0$."

The first part of this sentence (....this problem.....has no indirect solution....) is incorrect. Author remarks that, if the variable θ is not eliminated, Euler's equations in combination with the method of Lagrange multipliers lead to three possibilities: dive, zoom, $\omega(V, Z) = 0$. The calculus of variations, however, does not give any clear information about how to combine the afore-mentioned possibilities to obtain the optimum solution under the assumed boundary conditions of the fixed-end points problem. This information, on the contrary, is fully supplied by the method developed by the author in his paper.

The second part of this statement ("....even if he mentions it....") is incorrect, because the author did not mention it.

The last part of the sentence ("....without giving the effective

construction of the $V(Z)$ optimal end arcs through $(V_1 Z_1)$, $(V_2 Z_2)$ intersecting $(V, Z) = 0$") requires clarification. Reviewer refers to a problem briefly mentioned in the appendix to the paper. Author offered results without proof, because *he had already published such a proof in a previous article* (AMR 4, Rev. 3954). This article is listed in the bibliography of the present paper.

4 Reviewer states: "A conditional solution of flight technical interest is, however, given with extremals of $(V, Z) = 0$ central part and two $z = $ const end arcs. The minimal or maximal character of these extremals relative to the class of all possible arcs $V(Z)$ ending in $z = $ const pieces through (V_1, Z_1), (V_2, Z_2) can be proved by Riemann's formula."

Author remarks that reviewer has not appreciated paper's results which have a far broader character. As a matter of fact, the afore-mentioned solution is an extremal for the class of all the possible $V = V(Z)$ arcs passing through the points 1 and 2 and satisfying the limitation $Z_1 \leq Z \leq Z_2$. The $z = $ const end branches do not refer to the class of all arcs investigated, but only to those special arcs which have an extremal character.

5 Reviewer states: ". . .in an exact dynamical formulation of the problem. . . the integrand would not be linear in $V'(Z)$ and the Euler equation would be regular, i.e., differential of the second order. . . ."

Such a statement is incorrect. Author remarks that, even using a parabolic polar, the problem would be a fourth-order problem.   A. Miele, USA

Theoretical and Experimental Methods

(See also Revs. 3809, 3812, 3813, 3814, 3826, 3845, 3848, 3866, 3953, 3959, 3964, 4010)

3781. Madelung, E., **The mathematical tools of the physicist [Die Mathematischen hilfsmittel des Physikers], 5th ed. (Die Grundlehren der Mathematischen Wissenschaften, Bd. IV),** Berlin, Springer-Verlag, 1953, xx + 531 pp., 29 figs. DM 49.70.

This comprehensive, detailed, well-planned compendium is identical with 4th ed. but contains many significant improvements over 3rd ed. Mathematical topics include number systems, analysis, special functions, transformations, differential and integral equations, calculus of variations; also algebra, vectors, tensors, matrixes, determinants, groups, statistics. Physical topics include mechanics, elasticity, hydrodynamics, electrodynamics, relativity, quantum theory, thermodynamics, statistical methods. Topics are explained briefly to show coherent logical development of each subject. Formulas are listed profusely. Derivations, when given, are usually only outlined. Necessary brevity is mitigated by excellent references to works (mostly in German) containing full accounts of topics. A handy, successful reference work for applied mathematicians.

      B. Hoffmann, USA

3782. Bronwell, A., **Advanced mathematics in physics and engineering,** New York, London, Toronto, McGraw-Hill Book Co., Inc., 1953, xvi + 475 pp. $6.

This text is intended primarily for students in engineering and physics at senior and graduate level. An attempt has been made to develop fundamental formulations in fields which are the common ground of the physicist and the engineer. Solutions of typical problems are included in order to provide concrete examples of mathematical methods. It is author's opinion that this can be accomplished without devoting an excessive amount of time to the rigors of advanced mathematics.

First five chapters present a mathematical foundation in complex numbers, infinite series, solution of ordinary differential equa-

tions, and series methods of solving differential equations, including Bessel, Legendre, and associated Legendre equations. There follows a chapter on partial differentiation, which includes as an application some of the fundamental formulations in thermodynamics. Next two chapters are devoted to analysis of mechanical vibration and electrical oscillation in systems containing lumped and distributed elements, the latter forming a convenient preview of methods of solving partial differential equations. The Lagrangian method of formulating differential equations and its relation to Hamilton's principle and the action integral are considered. An introduction to vector analysis is given in chap. 10. Chap. 11 presents a general treatment of the wave equations, Laplace's equation, the heat-flow equation, and other linear partial differential equations. An attempt has been made to present a simple and unified approach to their solution.

Fundamentals of heat flow, fluid dynamics, and electromagnetic theory occupy chaps. 12 through 14. All equations for both compressible and incompressible fluid flow are derived from three fundamental equations, namely, Euler's equation, equation of continuity, and equation of state. Chap. 15 is devoted to functions of a complex variable. Dynamic stability of airplanes, servomechanisms, and electrical networks provide an interesting and useful application. Proofs of the Routh-Hurwitz stability criterion, the Nyquist criterion, and other stability criteria are presented together with applications in chap. 16. The final chapter presents an introduction to Laplacian methods in operational calculus.

Obviously such an ambitious program could be compressed into a limited space only by sacrificing rigor in some places. For more complete treatment or for rigorous proofs, whenever not given, reader is referred to standard texts, quoted at the end of each chapter. Subject matter and problems are ordered with increasing complexity. Answers to problems collected at end of book could be more complete, e.g., giving hints in such cases where theorems are required to be proved. Book could be said to contain the standard equipment of mathematical theories and formulas in daily use by the research worker in applied mechanics. Information concerning applications is brief, though usually sufficient and easily readable. In some cases, such as the explanation of the second law of thermodynamics, information given is not apt to clarify the matter to those unfamiliar with subject. Printing is excellent and typographical errors seem to be rare. Figures are, in general, good. Fig. 6 (p. 154) is misleading if compared with fig. 5 (p. 153), both indicating distributed load on beam. Book could be recommended to engineers and research workers who want to brush up their knowledge in this field.

      F. K. G. Odqvist, Sweden

3783. Khinchin, A. Ya., **A short course in mathematical analysis [Kratkii kurs matematicheskogo analiza],** Moscow, Gosud. Izdat. Tekh.-Teor. Lit., 1953, 624 pp.

Book is a first course for the study of advanced calculus at physico- and mechanico-mathematical faculties in the Russian universities. It constitutes an essential foundation of the theory of limits, series, given elements of differential and integral calculus, as well as simple applications.

This work of the world-renowned savant and excellent pedagogue will, no doubt, fulfill all purposes desired by its author. Presentation is perfectly rigorous but in no way cluttered with useless abstract considerations which usually make the transition from school mathematics to advanced calculus very difficult for beginners.

Author emphasizes philosophical and educational points of view. Reviewer believes that students themselves will recognize the usefulness and necessity of introducing new mathematical concepts. They will see how and where physics and engineering

lead directly to methods of higher mathematics. In spite of its comparatively small scope, the work explains many fundamental facts better than some voluminous courses on this subject. Many years' experience showed the author the most expedient way to group the matter into natural wholes (e.g., the mean value theorems in chap. 9, section on power series and series of polynomials in chap. 20, etc.). There are numerous and various applications to physics and technics.

Volume has 6 main parts divided into 29 chapters and 130 paragraphs. It concludes with a very fine historical summary and with a subject index. Content is evident from the titles and short characteristics of separate main parts: "Introduction to analysis" deals with functions of one variable, limits, and real numbers. "Elements of differential calculus" explains derivatives and differentials, the mean value theorems and extrema of functions. "Elements of integral calculus" defines the concept of integral, describes integrating basic classes of functions, and shows geometrical and mechanical applications. "Infinite series" contains series of numbers and functions as well as trigonometric series. "Further development of differential calculus" treats functions with more independent variables; and final section has for its subject the analogous questions of the integral calculus.

Book abounds in original ideals and characteristic educational methods. Style is excellent, paper and print very good. Reviewer cannot recommend any better introduction to advanced calculus to engineers and physicists.

V. Vodička, Czechoslovakia

3784.   Naimark, M. A., Linear differential operators [Lineinyiye differentsialnyiye operatory], Moscow, Gosud. Izdat. Tekh.-Teor. Lit., 1954, 351 pp.

The most important branch of mathematical physics and theoretical engineering, namely, solving boundary-value problems involving partial differential equations, cannot be studied without adequate knowledge of the theory of linear differential operators and their spectral analysis. For instance, many fundamental questions of quantum mechanics lead to treating singular differential operators and their spectra. There exists abundant literature on this subject. Unfortunately, it consists, for the most part, of discrete articles scattered in various periodicals and is not readily available to engineers and physicists. A reasonably systematic treatment of these concepts and methods can be found in courses of mathematical physics such as the well-known works by Courant-Hilbert, Sobolev, Smirnov IV-V, etc.

Only two books should nowadays be cited, in reviewer's opinion, as devoted exclusively to the subject in question. First, the "Eigenfunction expansions associated with second-order differential equations," by Titchmarsh, Oxford, 1946, and then Levitan's monograph "Expansion in series of eigenfunctions of second-order differential equations" (in Russian), GTTI, 1950. These works treat the associated questions by elementary methods, almost without any use of functional analysis. Moreover, they deal only with operators of second order. Thus there was an unpleasant gap in the literature up to the present time.

Naimark's work brings to the reader the most recent research in this field and presents, no doubt, the best and most complete treatise on the subject—being composed of 8 chapters and 26 paragraphs with 142 subtopics. The book presents the most modern viewpoint in the theory of differential operators of any order. It fills perfectly the long-felt gap in this important branch of scientific literature.

Volume is divided into two main parts. The first—containing three chapters—presupposes only basic concepts of functional analysis and author calls it "Elementary theory of linear differential operators."

Chap. 1 presents a general definition and basic properties of linear operators, the concept of their eigenvalues and characteristic functions, as well as the Green functions of such operators. Chap. 2 treats asymptotic behavior of proper values and of eigenfunctions, along with the methods of expansion in series of characteristic functions. Chap. 3 offers a theory of differential operators in the space of vector functions. All considerations in the first main part of the book relate to a finite interval. The study requires only adequate knowledge in the theory of ordinary differential and integral equations. Reviewer recommends that engineers and physicists at least peruse this "elementary" part of the volume.

Following five chapters are devoted to the advanced theory of linear differential operators in a Hilbert space and form the second main part. The subject is undoubtedly somewhat difficult for technicians, presupposing a reasonable familiarity with the theory of Lebesque's integrals.

Utility and importance of the material covered in this second part of the book can be seen from the contents of separate chapters: 4.   Basic ideas associated with general theory of linear operators in a Hilbert space.   5.   Symmetrical differential operators.   6.   Spectral analysis of differential operators.   7.   The defect and spectrum index.   8.   The inverse Sturm-Liouville problem. Major part of matters treated in the last two chapters presents contributions of Russian savants.

Volume ends with an abundant index of literature, both Russian and non-Russian. There is also a subject index. Paper is good, print excellent.

Reviewer feels that this book needs no recommendation. It should be studied by everyone who wishes to learn the subject as it should be learned.   V. Vodička, Czechoslovakia

3785.   Szabó, I., Integration and series expansion of ordinary and partial differential equations [Integration und Reihenentwicklung im Komplexen Gewöhnliche und partielle Differentialgleichungen] (Rothe, R., Higher mathematics [Höhere Mathematik] VI), Stuttgart, B. G. Teubner, 1953, 251 pp., 54 figs. DM 17.60.

This text is the fourth of a series entitled "Higher mathematics," first introduced by R. Rothe more than 30 years ago. The present text is written by I. Szabó. In the interim years from the appearance of the first volume, the mathematical needs of the physicist and engineer have grown considerably. The author attempts to provide some of these tools in about 247 pages.

The text is in four parts. In part I there is a compact treatment of the theory of functions of a complex variable, a brief outline of the Eulerian integral with its special cases leading to such well-known functions as the gamma function, etc. Some consideration is given to asymptotic series and other transcendental functions.

Part 2 considers special topics in the theory of ordinary linear differential equations for the second and higher orders. It treats matters such as the structure of the solutions of the homogeneous equation, self-adjoint equations, analytic dependence of the solutions on a parameter of the differential equation, singularities, integration of differential equations by means of a definite integral, and the Laplace transform.

Part 3 deals with the differential equations of the hypergeometric and Legendre types, the confluent hypergeometric equation and its special cases; the Bessel differential equation is treated in great detail. A good introduction to equations of second order with periodic coefficients is given here, together with a somewhat detailed account of the Mathieu equation and its applications to problems of stability.

Part 4 is a brief introduction to partial differential equations.

The quasilinear equation of first order is expounded with the usual geometric approach, and also the Cauchy initial-value problem is stated. More space is devoted to the second-order equations. Topics include the characteristic differential equation, transformation to normal form of the hyperbolic, elliptic, and parabolic cases. Methods of solution, such as Riemann's, are given together with examples; a brief introduction to the wave equation is also given.

The text does not consider theoretical aspects but is mostly concerned with the exposition of well-known methods of solution. There are many examples and problems. It can be recommended to the practicing engineer with a good mathematical background.

J. J. Brandstatter, USA

3786. Brousse, P., and Poncin, H., Some general results in the solution of elliptic-type equations with given boundary conditions (in French), "Mémoires sur la mécanique des fluides," *Publ. sci. tech. Min. Air, Paris,* 17-24, 1954.

Some general results are stated concerning the solution $V(x, y)$ of the partial differential equation

$$\nabla^2 V + (a_1/y)V_y + (a_2/y^2)V + a_3 = 0$$

with different values of the constants a_1, a_2, a_3, and subject to various boundary conditions. The equation occurs in modified form in a large number of physical problems.

A. R. Mitchell, Scotland

3787. Birman, M., Theory of general boundary problems for elliptic differential equations (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* 92, 2, 205-208, Sept. 1953.

By operational methods, Visik has recently established existence and uniqueness theorems for large classes of partial differential equations of second and higher order [title source 81, p. 717, 1951; 82, p. 181, 1952]. Present paper contains some remarks hereto and, without detailed proof, a theorem amounting to this: Let L be a self-adjoint elliptic operator with a domain of definition consisting of all functions twice derivable and vanishing at the boundary; further, L' the same but without boundary conditions. Then the closures of L and L' are adjoint to each other. A second theorem pertains to the "hard" self-adjoint extension as defined by Krein [*Mat. Sbornik* (2nd series) 20, p. 431, 1947].

G. Plato, Germany

3788. Bitzadze, A. V., Inversion of a system of singular integral equations (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* 93, 4, 595-597, Dec. 1953. (English translation by M. D. Friedman is on file with Scientific Translation Division, Library of Congress.)

The problem of solving a set of two-dimensional singular integral equations of the second kind on a surface S, with generalized Cauchy-type kernels, is transformed to a boundary-value problem. The unknown functions are then solutions of an elliptic system of first-order partial differential equations, similar to the Cauchy-Riemann equations, and they must satisfy a set of linear equations in the internal and external limit values on the surface S. This boundary-value problem is solved and interpreted as the solution of the set of integral equations.

H. G. Loos, Holland

3789. Shaw, F. S., An introduction to relaxation methods, New York, Dover Publications, Inc., 1953, 396 pp. $5.50.

Numerical techniques are detailed by diagrams and examples. Considered are linear algebraic simultaneous equations, linear ordinary, and second-order through fourth-order linear partial differential equations, eigenvalue problems, free surface problems, and integral equations. Clear treatment of differential equations takes up much of the work, particularly those equations encountered in many physical problems. Tabulated coefficients are included for problems having odd-shaped boundaries. Generous use of diagrams depicting mesh numbers, sketches of procedure, computing forms, clarify the method. Author leads the reader very nicely through each of the applications, which are general for the many different types of equations. A large historic bibliography is included. This 400-page book gives a general up-to-date report of the art, very useful for solution of physical problems.

J. DeYoung, USA

3790. Mendelson, M. J., The decimal digital differential analyzer, *Aero. Engng. Rev.* 13, 2, 42-54, Feb. 1954.

Characteristics and fundamental properties of the digital differential analyzer are presented in a straightforward and interesting manner. Operation of the digital integrator is described by comparing it with the conventional wheel-and-disk integrator. Several examples illustrate the number system used and the necessary interconnection between integrators for solving some simple equations.

A short description is given of the internal mechanization of a digital differential analyzer using a magnetic drum for the registers and delay lines. Scaling factors are discussed briefly, along with a few remarks describing the interconnection of integrators for special operations. These operations include the generation of $|f(x)|$, multiplication and division of two variables, and that of a decision integrator.

L. D. Findley, USA

3791. Lowe, J. R., The A.D.E. photo-electric integrator, *Nature* 173, 4417, 1222-1223, June 1954.

Paper describes an instrument for evaluating surface integrals of any function over a domain with any boundaries not containing poles of the function. Accuracy obtained in a particular known example was good. A measure of accuracy is indicated, but author withholds a more adequate statement, as work reported is of a preliminary nature.

Y. Luke, USA

3792. Rose, A., and Heiny, R. L., Computers, statistics and mathematics, *Indust. Engng. Chem.* 46, 5, 916-922, May 1954.

A survey of developments during 1953.

Ed.

3793. Azaroff, L. V., A one-dimensional Fourier analog computer, *Rev. sci. Instrum.* 25, 5, 471-477, May 1954.

An analog computer capable of summing up to 30 terms of a Fourier series is described. Trigonometric functions are produced by variable angle transformers and amplitudes are set on variacs. Currents are summed in parallel and are readable on a voltmeter and oscilloscope. Speed and error are compared with conventional strip methods.

H. D. Huskey, USA

3794. Schonfeld, J. C., Analogy of hydraulic, mechanical, acoustic and electric systems, *Appl. sci. Res.(B)* 3, 6, 417-450, 1954.

Author gives a rather complete and sometimes novel treatment of the analogies between linear hydraulic, electrical, and acoustic circuits. A symbolic scheme for the representation of the various elements of a hydraulic circuit is suggested. Unidirectional wave systems, such as wave systems in canals, are represented by simple hydraulic circuits in series.

The American reader may find the terminology and symbolism unfamiliar.

W. J. Carter, USA

3795. Lieblein, J., A new method of analyzing extreme-value data, *NACA TN* 3053, 88 pp., Jan. 1954.

Usual statistical methods apply to variations which arise from combined effects of a large number of more or less equally important small causes and hence have the Gaussian distribution. But variations dependent on the extreme variations of a number of underlying causes are of interest in engineering problems such as estimating the heaviest gust load, the biggest bump in a road, the largest flood, or the weakest element in a long bar or cable. This latter class of problem leads to one of three types of extreme-value distributions, depending on whether the initial distribution is exponential like the Gaussian, of the Cauchy type (like $1/x^n$), or has a finite limit. The author deals with the first of these distributions and provides techniques for answering such questions as, "Given the heaviest gust encountered on 20 flights, what will be confidence limits for the heaviest gust encountered on 100 such flights." The methods are applicable to sample sizes as small as two, although, of course, the confidence interval will then be very broad. For sample sizes of four or more, the efficiency of the estimates is 70% or better. The paper is a valuable aid in estimation from data drawn from a non-normal population. It is hoped that the author will have the opportunity to extend the work to the other extreme-value distributions.

F. A. McClintock, USA

3796. Abbott, I. H., Methods used by NACA for data reduction (in French and English), *AGARD Memo.* AG 3/M 2, 17 pp., Rome AGARD Conf., Dec. 1952.

Mechanization of data reduction at the NACA laboratories has proceeded along two lines: First, semiautomatic methods of processing data that are flexible in the sense that all kinds of data can be handled regardless of the source, type of data, or method of measurement; second, fully or nearly fully automatic methods that have been developed for processing or partly processing specific types of measurements that are made in a standardized manner.

A general discussion of both classes of methods is presented. A few examples are given of the types of data which are reduced to punched cards for the semiautomatic methods, and a brief description is given of the Digital Automatic Multiple Point Pressure Recording System at the Lewis Flight Propulsion Laboratory. This automatic system provides for the recording of a number of pressure readings in a period of ten seconds and the read-out of the values to magnetic tape at a rate of 20 pressures per second.

L. D. Findley, USA

3797. Pletta, D. H., and Frederick, D., Experimental analysis, *Proc. Amer. Soc. civ. Engrs.* 79, Separ. no. 224, 23 pp., July 1953.

Authors discuss necessary and sufficient conditions for a structural model to represent behavior of prototype. Application of theory of model analysis to reinforced-concrete beams was examined experimentally. Beams subjected to quarter-point loading and having dimensions in the ratio 1:2:3 were used.

Authors show that good agreement with model theory can be obtained, using relatively small models when both model and prototype are made of reinforced concrete of practically the same water-cement ratio and consistency. E. K. Frankl, England

3798. Lemke, C. E., and Charnes, A., Extremal problems in linear inequalities, *Carnegie Inst. Technol., Dept. Math. tech. Rep.* 36, 82 pp., May 1953.

The main subject is the solution of linear programming problems, i.e., optimizing a linear functional subject to constraints in the form of linear inequalities. Chap. 1 presents a finite iterative method of solving linear programming problems which they call the "dual" method. Then, after summarizing the Dantzig simplex method, a geometric visualization of both methods is given. Chap. 2 presents a "modified simplex" method for controlling round-off errors which appear in simplex method calculations. This modified method is currently being used in the program for solving linear programming problems on the IBM 701. Chap. 3 uses the dual method to consider (1) the problem of minimization of a positive-definite quadratic form over a convex polyhedron, and (2) some minimization problems involving the sums of absolute values of linear forms. Chap. 4 gives a method of matrix inversion and then applies this theory to the inversion of Leontief matrixes and to the problem of consolidation of Leontief systems. Appendixes 1 and 2 discuss dual degeneracy and finding an initial extreme point solution in relationship to dual method of chap. 1.

E. L. Arnoff, USA

3799. Comrie, L. J., Chambers' shorter six-figure mathematical tables, New York, Chemical Publishing Co., Inc., 1954, xxvi + 387 pp. $6.50.

This volume, compiled by a most competent author, is a well-organized mathematical tool. Very conclusive explanations and examples precede the work, covering each of the selected tables, starting with logarithms of numbers and trigonometric functions; trigonometric and circular functions; exponential and hyperbolic functions. The incorporation of Proportional Parts Tabulation offers convenient methods to those working without a calculating machine. The presented means of accurate interpolation and the use of reciprocals also suggest practical methods for the calculating machine. The final part featuring the derivatives, integral formulas, physical constants and mathematical constants, makes this book a very comprehensive collection.

C. R. Bell, USA

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 3782, 3840, 3843, 4095, 4097)

3800. Crossley, F. R. E., Dynamics in machines, New York, The Ronald Press Co., 1954, v + 463 pp. $7.

The author states that "this book is intended as a text for the intermediate course in dynamics given to junior or senior mechanical engineering students as a sequel to their introductory courses in statics, dynamics, and strength of materials" and, besides "applying these fundamental skills to the analysis of dynamic problems in machine design," it provides the student with a basic background for advanced study in kinematics, mechanisms, stress analysis, "theory of vibrations, mechanical servomechanisms, and general dynamics."

A recitation of the titles of the ten chapters, merely as a key to the contents, follows: Introductory kinetics, Equations of motion, Simple harmonic motion, Balance of rotors and critical speeds, Vibrations—damped and forced, Three-dimensional rotation, Static and dynamic forces in machines (rigid), Flywheels and engine balancing, Flexible machine members in motion, and Governors. Standard nomenclature is used throughout; examples and problems are prolific in each chapter. The sections of the book are separated for assignment of any desired chapters.

Excellent presentations of the phenomena of natural frequency, resonance, and critical speeds for a single degree of freedom are given, the effects of the nonrigid body in the study of balancing are explained, the behavior of the angular momentum vector as an aid in understanding the gyroscope and its applications is discussed, the effects of inertia forces in machines (especially engines) are considered, the effects of stress and strain on bodies are

examined, and the study of governors leads up to an interest in automatic control.

The book is well written and, although the presentation does not include exceptional challenges to the imagination, certainly the student would be aware of the possibility of continued study beyond each of the pages of the text. The book includes a large amount of material of a directed nature, tending to bridge the gap between elementary and advanced theory by applications practical to the mechanical engineer.

Much material is now presented in several courses; the combination suggested here, with a textbook as complete and well written as this one, would be worth the effort. Not only is this study of dynamics useful for all mechanical engineers, but also the arrangement forms a basic transition for the advanced courses.

I would commend the author for his understanding of the problem and the thoroughness of his presentation.

J. J. Ryan, USA

3801. Cox, G. N., and Plumtree, W. G., Engineering mechanics, 2nd ed., Toronto, New York, London, D. Van Nostrand Co., Inc., 1954, ix + 382 pp. $5.50.

This is the 2nd edition of the usual-type elementary mechanics text prepared for undergraduate engineering students in the United States. The content by chapter is as follows: 1. Fundamental concepts, definitions, and principles; 2. Resultants of coplanar force systems; 3. Equilibrium of coplanar force systems; 4. Analysis of simple structures and flexible cables; 5. Friction (a discussion of some of the more recent work has been included here); 6. Noncoplanar force systems; 7. Centroids; 8. Moments of inertia; 9. Kinematics; 10. Kinetics of rigid bodies—Force-inertia method; 11. Work, energy, and power; 12. Impulse and momentum; 13. Simple harmonic motion and mechanical vibrations.

The number of problems (mostly numerical) has been increased and answers have been provided for approximately half.

J. L. Bogdanoff, USA

3802. Bullock, M. L., Systems of units in mechanics—a summary, *Amer. J. Phys.* 22, 5, 291–299, May 1954.

3803. Muller, W., Railway installations and traction dynamics [Eisenbahnanlagen und Fahrdynamik], vol. 2, Berlin, Springer-Verlag, 1953, xi + 356 pp., 102 figs., 30 tables. DM 52:50.

This book gives a most useful exposition of traction performance determinations, the calculation of operating expenses as determined by the tractive effort and fuel-consumption characteristics of locomotives, and the determination of the ton-mile capacity of standard-gage railway lines. The treatment of train performances and the resultant fuel expenses is of particular interest and here the author's graphic method of time-distance determination provides a valuable tool. The use of the methods evolved is illustrated for steam and electric-drawn trains. The book represents a thorough and readable text on an important subject which so far has not received the consideration due to it.

In reviewer's opinion, the text can be highly recommended to designers and theoretically minded railroad operators as well as to engineers who are willing to consider rolling stock and line performance on a scientific basis.

Chapter headings are: Fundamentals of traction dynamics; Determination of single-trip fuel consumption. Train performance on grades. Brake performance nomograms. Costs of train operation. Determination of total railway operating expenses. Determination of economically justified gradients. Determination of line capacity. J. L. Koffman, England

3804. Dauner, W., Hiller, E., and Reck, W., Introduction into the wheel flange mechanics of rail vehicles (in German), *Arch. Eisenbahntech.* no. 2, 1–28, 1953.

The purpose of this paper is to make available the results of theoretical investigations carried out between 1941 and 1944 by a research group set up by the Ministry of Communications to deal with problems of vehicle mechanics in the horizontal plane. The research resulted in the publication in 1951 by the Central Railway Dept. at Munich, for official use, of nine booklets under a common title of Provisional Directions for the Construction of Rolling Stock to Ensure Good Guidance on Rails. The present paper should make the main results available to a wider circle and serve as an introduction to an aspect of railway mechanics which has generally not received the consideration due to its economic importance.

The first part of the paper deals with flange forces of single wheel sets, while the position of wheels passing constant radius curves at a steady speed are considered in the second part. The determination of flange forces and vehicle positions with the help of graphical methods due to Heumann, Ubelacker-Vobel, Troitsch, and Hiller are considered in some detail. The third part is devoted to the effect of dynamic forces caused by track irregularities or vehicle faults as well as by uncompensated centrifugal forces, sudden changes of curvature, horizontal track, and vehicle stiffness, etc., on flange forces and to the problem of derailing. The last part deals with practical applications of these considerations to the design of rolling stock, with particular reference to bogie cars, locomotives, and articulated vehicles. The bibliography numbers about 290 papers, mostly of German origin.

The paper fulfills its objective and should be of value to rolling-stock designers and research engineers. Reviewer found that, by consistent application of some of the data discussed, very satisfactory results were achieved with a number of light railcars of novel design. J. L. Koffman, England

3805. Odier, J., Contribution to the study of the influence of temperature on friction problems (in French), *C. R. Acad. Sci. Paris* 238, 12, 1288–1289, Mar. 1954.

3806. Tzenoff, I., The determination of the translation and rotation of a rigid body, if the velocities of three points on the body are given (in Serbian), *Godishnik, Univ. Sofia* 47, sec. 1, part 2, 59–66, 1950/51–1951/52.

The three-dimensional motion of a rigid body is mathematically analyzed as a combination of translation and rotation. The author derives the vectorial relationships among the angular rotation of the body about O, the origin of coordinates, the translational velocity of the origin, the velocities of three points on the body, and the space configuration of these points. It is assumed that the velocities and location of the three points are known, and so the derived equations are solved for the rotational velocity component and for the translational velocity component. The complete lack of free bodies and sketches, as well as the use of uncommon operational notations, makes it difficult to follow the text. J. P. Vidosic, USA

3807. Eckart, C., Relation between time averages and ensemble averages in the statistical dynamics of continuous media, *Phys. Rev.* (2) 91, 4, 784–790, Aug. 1953.

Paper is devoted to methods of calculation of averages pertaining to the field equation $Lp = \delta p/\delta t + a(xt)$ where L is a linear operator such that $Lf = -i\omega f$ has no discrete eigenvalues and $a(xt)$ is a vector-time function acting as a driving force. Using convolutions and correlations, time averages may be determined without finding analytic solutions for the field equation.

Ensemble averages are built by weighting functions over the class of solutions. The Parseval theorem and Schwartzian inequalities are employed to point out limitations to the method. Application to dissipative systems and scattering of radiation by fluctuating refraction indexes are discussed.

Basic definitions and theorems can be found in Wiener, N., "Extrapolation, interpolation and smoothing of stationary time series," John Wiley & Sons, 1949.   E. C. Varnum, USA

Servomechanisms, Governors, Gyroscopics

(See also Rev. 3800)

3808. Beharrell, J. L., and Friedrich, H. R., The transfer function of a rocket-type guided missile with consideration of its structural elasticity, *J. aero. Sci.* 21, 7, 454–458, July 1954.

The present trend to reduce missile fabrication weight per pound propellant for a given payload and range leads to doubts concerning the accuracy of a rigid-body representation of missile pitching and yawing motions. In an attempt to improve the representation, missile motion is described by an elastic free-free beam with given mass and stiffness distributions. The transfer function is then derived, using the Laplace transformation, relating control deflection angle to displacement gyro measured angle at any point on the missile longitudinal axis. It is assumed that structural damping is negligible and that aerodynamic restoring and damping forces are dependent only on the rotary motion of an equivalent rigid missile. In a general control block diagram, the derived transfer function can be represented by a basic block for the rigid body motion with an additional parallel block for each vibration mode considered. This permits investigation of the effect of gyro longitudinal location on the stability qualities of the closed pitch and yaw control loops. No attempt has been made by the authors to present similar equations for translational motion or for combined translation and rotation.
                                                          R. M. Spath, USA

3809. Vowels, R. E., The application of statistical methods to servomechanisms, *Austral. J. appl. Sci.* 4, 4, 469–488, Dec. 1953.

The optimum transfer function for the desired response to a stationary random input signal containing noise may be determined by the method detailed by Wiener and Lee. This procedure, when applied to servomechanism design, does not, however, necessarily yield a zero steady-state error. This advantage can, however, be obviated by conjoining restraints on the Wiener-Hopf equation such that one or more of the error coefficients of the servomechanism are made zero and simultaneously the output is optimized as closely as certain practical considerations permit. It also proves possible to encompass prediction, differentiation, or integration of the input function as desired outputs. Following the formulation of the basic theory as just epitomized, a simple illustrative example is detailed to exemplify the course of analysis in general.   T. J. Higgins, USA

3810. Evans, W. R., The use of zeros and poles for frequency response or transient response, Frequency Response Symp., ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-24, 5 pp.

Control systems are considered for which the input-output ratio can be written as $R(s) = 1/KG(s) + 1$, where K is a parameter and $G(s) = (s - q_1)(s - q_2)\ldots/(s - p_1)(s - p_2)\ldots$ Frequency response is obtained by calculation of $R(s)$ for purely imaginary values of s. In order to find the roots s_i of the characteristic equation $1/KG(s) = -1$, the locus of s for varying K is sketched

by determining those points of the complex s-plane for which the angle of the vector $G(s)$ is 180°. This is performed by reading in the s-plane the angles of all factors of $G(s)$. A point of the locus is a root if $K = 1/|G(s)|$. Having obtained the roots s_i, transient response for given initial conditions follows by aid of usual method of Laplace transformation.
                                              A. I. van de Vooren, Holland

3811. Bubb, F. W., Direct synthesis of servomechanisms, *WADC Tech. Rep.* 53–420, 125 pp., June 1953.

A very clear presentation of the application of Bubb's polynomial transforms [AMR 4, Rev. 4370] to servomechanism design. Assumes no previous knowledge of method of polynomial transforms, which is presented anew in part 1. Part 2 explains how to design a servo having a specified response to a step-function input. Part 3 gives a numerical example, completely worked out, leading to a servo of $1/2$ hp with amplidyne and $P + D + I$ equalizing network. Appendixes A and B are well-known chapters of servo theory, making the whole presentation self-contained. A useful addition to servo literature.
                                                      P. Le Corbeiller, USA

Vibrations, Balancing

(See also Revs. 3782, 3800, 4065)

3812. Radok, J. R. M., and Heller, A., The exact solution of the integral equation of certain vibration problems (in German), *ZAMP* 5, 1, 50–66, 1953.

The integral equation

$$Z(y) - \omega^2 \int_0^1 K(y, \varphi) Z(\varphi) d\varphi = 0$$

with

$$K(y, \varphi) = \begin{cases} a_n y^n + a_{n-1} y^{n-1} \varphi + \ldots + a_0 \varphi^n; & \varphi < y \\ a_n \varphi^n + a_{n-1} \varphi^{n-1} y + \ldots + a_0 y^n; & \varphi > y \end{cases}$$

representing certain dynamic systems with polynomial mass and stiffness distribution, can be solved to any desired approximation by putting

$$Z(\varphi) = \sum_{j=0}^{k} \sum_{l=0}^{n} A_{L,j} \varphi^{j(n+1)+l}$$

taking k sufficiently great. Substitution and comparison of coefficients yield a recurrence relation

$$A_{L,j} = \omega^2 A_{L,j-1} C_{(j-1)(n+1)+l}$$

$C_m \equiv C(m, n, a_n, \ldots a_0)$ and a set of $n + 1$ linear homogeneous equations in $A_{L,0}(l = 0, \ldots n)$. The issuing characteristic equation is a polynomial of degree kn in ω^2. Important point is that it is relatively easy to proceed, in numerical applications, from k to $k + 1$ and thus to improve accuracy and number of obtained modes stepwise. Paper leaves some unclarity about relation of approximate to exact solution and of approximate characteristic equation to exact characteristic equation. Pertaining discussion seems to involve one or more slight errors.

Application is presented to bending vibrations of uniform beam and of wedge, both clamped at one end. Known exact solutions are successfully obtained by letting $k \to \infty$.
                                                    J. H. Greidanus, Holland

3813. Graffi, D., On the periodic vibration of nonlinear systems with many degrees of freedom (in French and Italian), *Publ. sci. tech. Min. Air, Paris* no. 281, 189–193, 1953.

Author considers two electrical circuits coupled by induction

If the resistances, capacitances, and inductances are constant, then the very well-known simultaneous differential equations for these two circuits are linear. The author assumes that the resistances are functions of the current and the two equations cease to be linear. When resistances vanish, then the equations become linear again; the solutions are periodic with two admissible periods T_1 and T_2, and $T_1 < T_2$. Under the assumption that the nonlinear system has a periodic solution with period T, author proves that $T > T_1$; or, stating it verbally: the above system of nonlinear equations always has a period which is greater than the smaller period in the system where the nonlinear terms are absent.

Two circuits imply two degrees of freedom, but the author claims that his theorem can be extended to a system of many degrees of freedom.   T. Leser, USA

3814. Roberson, R. E., On an iterative method for non-linear vibrations, *J. appl. Mech.* **20,** 2, 237–240, June 1953.

A modified Picard iteration process for the calculation of periodical solutions of differential equations is considered. The process is applied to forced oscillations of nonlinear systems with two degrees of freedom and nonlinear dissipative systems.

D. Graffi, Italy

3815. Aggarwal, R. R., Axially symmetric vibrations of a finite isotropic disk. III, *J. acoust. Soc. Amer.* **25,** 3, 533–535, May 1953.

Graphically solving the frequency equation, the different real values of α for the same frequency have been obtained. When three such values of α exist, three independent boundary conditions have been made to satisfy at the curved surface of the disk. The resonant frequencies for which these conditions hold good have been evaluated, and the corresponding displacement curves for the vibrating faces of the disk have been compared with the experimentally obtained curves for the barium titanate disks. A test for the validity of this method has been provided by comparing the residual stresses at the curved surface with the compressional component of the stress at the center of the disk.

From author's summary

3816. Aggarwal, R. R., and Shaw, E. A. G., Axially symmetric vibrations of a finite isotropic disk. IV, *J. acoust. Soc. Amer.* **26,** 3, 341–342, May 1954.

The method described in part 3 (preceding review) has been applied to another normal mode of a particular disk by combining the motions corresponding to the one imaginary and two real values of α. The residual stresses at the cylindrical surface of the disk are small, and the displacement distribution of the plane surfaces agrees reasonably well with that obtained experimentally.

From authors' summary

3817. Herrmann, G., Forced motions of elastic rods, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-59, 4 pp.

Formal solution is obtained for problems of free and forced longitudinal vibration using the one-dimensional approximate theory of Mindlin and Herrmann [AMR 5, Rev. 1308], which takes into account radial inertia and shear. Method uses the Lagrange equations of motion. No numerical results are given.

L. Malvern, USA

3818. Funaioli, E., Vibrations of warped, cantilevered plates (in Italian), *Aerotecnica* **33,** 3, 220–230, June 1953.

The effect of a slightly warped surface on the flexural vibrations of cantilevered thin plates of constant thickness is studied.

In particular, the first three modes of square plates are considered. As in the case of flat plates, the first and third modes are symmetric with respect to the axis of the plate perpendicular to the fixed edge, while the second mode is antisymmetric. For the two symmetric modes, the warping decreases the natural frequency, while frequency increases with increased warping in the antisymmetric mode. The normal displacements of points on the middle surface of the plate have a distribution which, especially for the two symmetric modes, is almost identical with that of a flat plate.

From author's summary by F. DiMaggio, USA

3819. De Pater, A. D., The free lateral vibrations of a railway vehicle on bogies at rest (in Dutch), *Ingenieur* **65,** 41, W162–W166, Oct. 1953.

Article deals with the free lateral vibrations of a symmetric railway vehicle at rest, standing on two bogies with bolster suspension. The superstructure and the frames of the bogies can move like rigid bodies with six degrees of freedom each. When the vehicle does not move over the rails, 7 of the 18 variables are identically zero. The remaining 11 are split up into a group of 6 describing the symmetric movements and a group of 5 describing the lateral vibrations. The equations of motion for the latter case are found by the Lagrange method. By a judicious transformation of the variables, another separation is made into a principally yawing motion in two degrees of freedom, and a hunting one, containing the remaining three. In both cases, simple formulas for the natural frequencies are given.

W. H. Muller, Holland

3820. Friel, F. J., Application of strain gauges to vibration surveys, *Proc. Soc. exp. Stress Anal.* **11,** 1, 1–6, 1953.

The vibrational characteristics of complex structures are of general interest in the study of their dynamic response to transient and periodic forces. A survey was made on a simple ring. This ring was first excited by steady-state forces applied by means of an electromagnet and its resonant frequencies were determined. The ring was then struck hard and soft blows and the resultant frequencies were observed. Good agreement was obtained between the frequencies observed under transient and under steady-state excitations. Vibration detectors and strain gages were used for the measurement of the vibration. A difference between the calculated and measured frequencies is not explained. There is no bibliography.   R. O. Fehr, USA

Wave Motion, Impact

3821. Kolsky, H., The propagation of longitudinal elastic waves along cylindrical bars, *Phil. Mag.* (7) **45,** 366, 712–726, July 1954.

Author considers cases in which ratio of length of bar to its radius is (a) about unity, (b) much larger. Experimental method consists in initiating elastic pulse at one end-face of cylinder and recording waves at opposite end using condenser microphone and oscillograph.

For short cylinders of type (a), the results show that propagation of short pulse involves consideration of various dilatational and distortional waves reflected before reaching microphone; such separate pulses are shown on experimental records. Pochhammer theory is inadequate to explain these results, but is adequate for long cylinders of type (b), where recorded pulse has tail of low-frequency oscillations. It is found that most of the energy travels with velocity less than c_0 (plane-wave velocity)

but some travels with velocity between c_0 and c_1 (dilatational velocity).

Reviewer regards paper as elucidating many points about wave propagation in bars.   D. H. Trevena, Wales

3822. Oudart, A., Point of impact of a circular cylinder and depth of impulsion (in French), "Mémoires sur la mécanique des fluides," *Publ. sci. tech. Min. Air, Paris*, 241–249, 1954.

The formulas of Hiemenz give infinite impulseless thickness at the point of impact of a circular cylinder when the radius becomes infinite, whereas the corresponding problem of Falkner and Skan (potential velocity $U = U_1 x$) gives a finite value. Author shows that there is no discrepancy when the limit process is done in a proper way. It is also shown that the impulseless thickness becomes zero for the other limiting case of sharp-nosed bodies.
                                                                W. Wuest, Germany

3823. Sakurai, A., On the propagation and structure of a blast wave, II, *J. phys. Soc. Japan* 9, 2, 256–266, Mar./Apr. 1954.

As a continuation of part I [AMR **7**, Rev. 1403], the second approximation for the propagation and structure of a blast wave is now discussed. The solution for $\gamma = 1.4$ is obtained by a numerical method, using the results of the first approximation obtained in part 1. By use of this solution, the U-R curves, distance-time curves, and the changing feature of distributions of velocity, pressure, and density behind the shock front are discussed.

Further, the approximate solution of the equation is discussed by a refinement of the WKB method due to Imai.
                                                                From author's summary

3824. Francis, J. R. D., Wave motions and the aerodynamic drag on a free oil surface, *Phil. Mag.* (7) **45**, 366, 695–702, July 1954.

Wind-tunnel experiments are described in which air is drawn over viscous oil. At low wind speeds no waves appear, but at a sharply defined critical wind speed small ripples appear, some ripples grow quickly, and the aerodynamic drag coefficient of the surface increases rapidly. Author concludes growth of ripples is due to Kelvin-Helmholtz-type instability [Lamb, "Hydrodynamics," 6th ed., Dover, 1945, art. 268], rather than to the "sheltering" process proposed by Jeffries [op. cit., art. 348]. The basis for this conclusion is that in the theory of Kelvin and Helmholtz, instability sets in at 516 cm sec^{-1}, while observed values (extrapolated to 0.05 cm above liquid level) were 530 ± 30 cm sec^{-1}. Author states that Jeffries' theory predicts first ripples at 570 cm sec^{-1}, but fails to note that this applies for an anemometer well above the liquid. In view of the fact that Kelvin and Helmholtz hypothesized no vertical gradient in wind speed, reviewer believes their theoretical model will only permit a rough comparison with experiment and that author's conclusion is unfounded.   C. Cox, USA

Elasticity Theory

❧**3825. Swainger, K., Analysis of deformation. Vol. I. Mathematical theory,** New York, The Macmillan Co.; London, Chapman & Hall, Ltd., 1954, xix + 285 pp. ($12.75); 63s.

This book is the first of a two-volume work on the analysis of deformation. Author presents a formulation of the mathematical theory only and reserves application of the theory for the second volume. Mathematical theory is formulated in three dimensions and vector-dyadic notation is used throughout.

There are nine chapters and three appendixes. Chaps. 1, 2, and 3 treat Displacement (36 pp.), Stress (30 pp.), and Strain (26 pp.), respectively. Remaining chapters discuss relationships between stress and strain for particular types of substances. Thus, chaps. 4, 5–9 are entitled: General considerations on stress and strain (30 pp.), Thermal considerations (6 pp.), Isotropic elastic substances (40 pp.), Viscoelastic isotropic substances (4 pp.), Yield (16 pp.), and Elastoplastic isotropic substances (25 pp.). An appendix on Vector analysis (30 pp.) is included for the reader unfamiliar with Gibbs' vector notation. Lastly, two appendixes entitled Scalar analysis (1 p.) and Potential theory and related theorems (2 pp.) conveniently collect information used in the text.

The book is well laid out. A brief history is given at the end of each chapter and a chapter-by-chapter glossary of terms is contained at the end of the book. Author presents a highly original treatment of deformation. He proposes a mathematically linear theory to analyze finite deformations and claims that this new theory indicates deficiencies in the "old theory." Reviewer believes that this one feature alone will cause considerable controversy.

The subject matter of this book is of great interest to engineers. However, many a potential reader, especially in the United States, will wish that the author had used the tensor notation, which has largely superseded the dyadic notation.
                                                                M. C. Steele, USA

3826. Sherman, D. I., Properties of infinite systems of equations in problems for torsion of certain doubly connected contours (in Russian), *Prikl. Mat. Mekh.* **17**, 4, 470–476, July/Aug. 1953.

Torsion problems for bars with multiply connected cross sections may be solved approximately by reduction of certain Fredholm equations to systems of algebraic equations. [AMR **2**, Rev. 1111; **6**, Rev. 2197]. Study of these systems for two particular numerical cases shows that they are regular.
                                                                J. R. M. Radok, USA

3827. Das, S. C., On the effect of a small spherical cavity in a semi-infinite elastic solid under stresses produced by a couple on the plane boundary, *Bull. Calcutta Math. Soc.* **45**, 3, 89–93, Sept. 1953.

As indicated by the title, author solves the problem of the semi-infinite solid containing a spherical cavity when the solid has acting on its plane surface a couple with its axis perpendicular to the plane surface. The problem is set up in terms of dipolar coordinates and the stresses are found as convergent infinite series involving Legendre's functions.   E. Saibel, USA

3828. Lur'e, A. I., Equilibrium of an elastic hollow sphere (in Russian), *Prikl. Mat. Mekh.* **17**, 3, 311–332, May/June 1953.

The solution is obtained for two boundary-value problems of a hollow sphere, namely when the displacements and the stresses are prescribed on the inner and outer surfaces. The latter is a new solution. The method applied is a variation of the W. Thomson or the Trefftz method of representation of the general solution of problems of elasticity in terms of displacements by three harmonic functions. Thomson expressed these functions in terms of harmonic polynomials, each of which in turn was determined from the boundary conditions. Instead of three harmonic functions, Lur'e, following P. F. Papkovich, employs four harmonic functions. The latter simplify the solution and reduce the amount of formal computation, and the compactness of the solution is obtained by application of vector notation.

The problem of the equilibrium of an elastic hollow sphere is about to celebrate its first centenary. In 1859, G. Lamé in his

"Leçons" was the first to consider this problem. He made, however, an additional assumption as to the form of the external forces. Next, W. Thomson in his "Treatise," 1883, succeeded in obtaining a solution of the first boundary-value problem. For the second, he outlined the method of construction of the equations. Galerkin, 1942, solved this latter problem for the axially symmetrical case. R. M. Evan-Iwanowski, USA

🖙3829. Melan, E., and Parkus, H., Thermal stresses due to steady-state temperature fields [Wärmespannungen infolge stationärer Temperaturfelder], Wien, Springer-Verlag, 1953, v + 114 pp., 30 figs. $4.40.

Book is a comprehensive, concise, and perspicuous exhibit of the theory and application of thermal stresses in stationary temperature fields. All characteristics of materials are assumed to be independent of temperature.

After a brief introduction of the principles of heat transfer, the basic thermal elastic equations of equilibrium and compatibility are derived. A thermal elastic displacement potential with the ensuing Poisson's equation are introduced. Conditions for temperature fields free of stresses are established. The principle of virtual displacement is applied to plane systems of thin bars under the influence of a change in temperature. The thermal stresses due to two-dimensional temperature fields are analyzed and many illustrative examples are solved to elucidate the methods used. The thermal stresses in plates are studied under the assumption of linear temperature distribution through the plate thickness and neglecting the normal stresses in the direction of plate thickness. Here also several examples show clearly the procedure to follow in the solution of problems. Thermal stresses in a solid of revolution and in shells due to axially symmetrical temperature field are investigated. The solutions of basic equations are procured with the aid of thermal displacement potential and Love's displacement function.

Interesting problems show the application of the above method. Stresses are calculated in a body with rectangular and spherical inclusions of different coefficient of expansion. This book, with its excellent clear and accurate representation, is a valuable addition to the technical literature. W. Ornstein, USA

3830. Paria, G., Stresses in an infinite strip due to a nucleus of thermo-elastic strain inside it, Bull. Calcutta math. Soc. 45, 3, 83–87, Sept. 1953.

An infinitesimal area surrounding the origin of an infinite strip $|x| \leq a$ of a thin plate is kept at a fixed temperature T. The remainder of the strip is kept at zero temperature.

First, Goodier's expressions for the stress due to a nucleus of thermoelastic strain in the infinite plate are written down. A second stress system in the form of Fourier integrals is then superposed in order to make the edges stress-free.

H. Parkus, USA

3831. Melan, E., Thermal stresses in a circular tank due to warm contents (in German), Öst. Bauzeitschr. 9, 5, 81–84, May 1954.

Thermal stresses are determined in a circular cylindrical tank partially filled with some matter whose temperature is higher than that of the surroundings. Stationary temperature fields are assumed. The thickness of the tank wall is very small in comparison with its diameter. All the equations are carefully and clearly derived and the boundary conditions set up. Several tables and diagrams are prepared to facilitate the numerical solution of similar problems. An example is calculated to illustrate the procedure to follow in the solution of problems.

W. Ornstein, USA

Experimental Stress Analysis

3832. Lamble, J. H., and Bayoumi, S. E. A., A room temperature photo-elastic technique for three-dimensional problems, Instn. mech. Engrs. Proc. (B) 1B, 12, 575–579, 1952/1953.

A sandwich technique is described which permits the observation of the photoelastic fringe pattern of the principal plane in three-dimensional models. The sandwich model consists of a thin slice of birefringent Catalin 800 forming the principal plane in a model otherwise composed of relatively insensitive Perspex. An essential element of the technique requires that the elastic modulus of the Catalin be increased by additional curing to match that of the Perspex. The model components are bonded together using Perspex cement; loading and examination of the model are conducted at room temperature. Confirmation of the accuracy of the technique is provided by a study of stresses in a notched, round bar. Other applications are also recorded.

W. Shelson, Canada

3833. Crisp, J. D. C., The use of gelatin models in structural analysis, Instn. mech. Engrs. Proc. (B) 1B, 12, 580–588, 1952/1953.

The thesis of this paper is that gelatin in photoelasticity can be applied successfully as a potent means of quantitative stress analysis of body-force structures capable of representation as plane elastic problems. A valid simulation of a prototype is derived, in general terms, in accordance with similarity principles, and the choice of model materials is shown to be vital in any particular application. Details of model construction are given and mention is made of the important influence of model thickness, temperature control, and polariscope design on the attainable accuracy of calibration and stress patterns. The exposition is illustrated by reference to the problem of the elastic, untied, bulkhead that retains an elastic mass by virtue of its flexural rigidity.

From author's summary by W. Shelson, Canada

3834. Brown, A. F. C., and Hickson, V. M., A photo-elastic study of stresses in screw threads, Instn. mech. Engrs. Proc. (B) 1B, 12, 605–608, 1952/1953.

The distribution of load in threaded connections was investigated photoelastically using three-dimensional Fosterite models. The experimental results support analyses by D. G. Sopwith which showed a large rise in stress in the stud near the bearing face of an ordinary nut and a much more uniform stress distribution when special tapered nuts and studs were used.

The stress concentration factors for the ordinary nut and stud were found to be higher than those previously determined by M. Hetényi. The difference is attributed to improved techniques and the use of Fosterite. W. Shelson, Canada

3835. Fessler, H., "Frozen stress" phenomenon in photo-elasticity, Instn. mech. Engrs. Proc. (B) 1B, 12, 613–620, 1952/1953.

Tensile tests were carried out at different temperatures and under different stresses on Marco resin, Fosterite, and Bakelite. The paper describes the experimental procedures and provides curves of fringe order vs. time for various temperatures. Curves of fringe-stress coefficient, modulus of elasticity, and figure of merit vs. temperature are also included. An increase in fringe order during cooling under constant stress was noted.

W. Shelson, Canada

3836. Koch, W. M., and Szego, P. A., Use of double-exposure photography in photoelasticity, J. appl. Mech. 21, 2, p.198, June 1954.

3837.   Noton, B. R., Experimental investigation of the stress distribution in a plastic model of a 35° sweptback wing with multiweb construction, *Flygtekn. Försöksanst.* no. 47, 44 pp., 1953.

Paper gives detailed description of test equipment, experimental procedure, and test results of an experimental investigation on a doubly tapered, thick-skin, Perspex model wing. Wing had five spars and a few ribs perpendicular to the rear spar. Five tests were made, in each case the load being applied at one of five points on each wing-half to provide a prescribed symmetrical deflection. Loads on port and starboard-half differed 15%, approximately. Extensive strain measurements were made on port top surface and on spar and rib webs. Results are presented very fully and critically discussed. No comparison is made with calculated stresses.   F. J. Plantema, Holland

3838.   Perley, R., Automatic strain-gage and thermocouple recording on punched cards, *J. Assn. comp. Mach.* 1, 1, 36–43, Jan. 1954.

3839.   Ruzek, J. M., Knudsen, K. E., Johnston, E. R., and Beedle, L. S., Welded portal frames tested to collapse, *Proc. Soc. exp. Stress Anal.* 11, 1, 159–180, 1953.

A testing method is described for investigating the behavior of full-size welded steel portal frames through the elastic and plastic range to collapse. Techniques and instrumentation are discussed for measuring deflections, rotations, curvatures, strains, and loads. Some of these are new and ingeniously designed for the large deformations which occur in the plastic domain.

G. Winter, USA

3840.   Buckner, H. A., Jr., and Rebeske, J. J., Jr., Application of high-speed strain-gage torquemeter to turbomachinery research, ASME Semi-Ann. Meet., Pittsburgh, Pa., June 1954. Pap. 54—SA-23, 13 pp.

Torquemeter described was used successfully by authors in measuring torques at rotational speeds as high as 17,000 rpm. Strain-gage bridge unbalance signals were taken off through slip rings. Brush-slip ring series resistance was kept below 5 ohms and brush noise level was held to an acceptable level by such precautions as use of (1) monel-metal slip rings ground to a concentricity of ±0.0002 in., (2) silver-graphite brushes, (3) two brushes on each ring, (4) a carbon tetrachloride flushing system for cleaning the rings periodically during a test, (5) a solenoid arrangement for applying brushes to rings only during time of reading, (6) brush pressures of 20 to 40 psi, (7) torsion shaft designed for torsion stresses of 15,000 to 25,000 psi. Effect of contact resistance was minimized by using multiple bridge arrangement described in *NACA TN* 1031, 1946.   E. A. Ripperger, USA

Rods, Beams, Shafts, Springs, Cables, etc.

(See also Revs. 3817, 3872)

3841.   Craemer, H., Load distributing effect of a plate upon beams, *Civ. Engng. Lond.* 49, 575, 510–513, May 1954.

Considering a plate rigidly connected to several parallel beams, the author considers the effect ("slab effect") of the applied load on a beam and that distributed on the adjacent beams, the bending stiffness of the plate in transverse direction only being taken into account. The effect ("disk effect") of the induced strains due to longitudinal stresses of a beam is also considered under the assumption of linear variation of strains in the plate. In a system of n plate panels and $(n + 1)$ beams the differential equations derived from consideration of above two effects, together with equilibrium conditions, are $(4n + 2)$ in number, from which

$(4n + 2)$ unknowns may be solved satisfying boundary conditions. As an illustration, a simple case of a regular symmetrical system has been worked out in some detail.   D. N. Mitra, India

3842.   Shepley, E., Influence lines for continuous beams, *Concr. constr. Engng.* 46, 2, 63–69, Feb. 1954.

3843.   Heumann, H., The strength of unequal-addendum involute gears (in German), *Maschinenbau-Technik* 2, 10, 454–459, Oct. 1953.

Paper derives analytical formulas for form factors for use in gear-tooth strength calculations (Lewis formula), for involute unequal-addendum gears. Design charts are given relating form factor to number of teeth and addendum factor. Since many gear designs are based on dynamic strength and wear considerations, reviewer suggests that this work be extended to include these effects.   G. A. Nothmann, USA

3844.   Tchudakov, E. A., edited by, Automobile suspensions [Podveska avtomobilya], A symposium of monographs, Moscow, Izdat. Akad. Nauk SSSR, 1951, 275 pp.

Fifteen separate papers are presented. They are the results of laboratory and field work based on extensive mathematical studies so rarely encountered in the investigation of automotive riding comfort and road stability. The editor, in his introduction, points out that the automotive suspension problem has to take account of so many parameters that a standardized analytical approach does not seem to be in the offing. This is probably one of the reasons that some duplication in the presented papers is encountered. V. B. Tzimbalin, in the opening chapter, analyzes the parameters and their order of magnitude used in evaluating the riding qualities of an automobile. He gives ten references to previous Russian work. "Appraisal of automobile suspensions taking account of the physiology of the rider" is treated by Y. I. Bronstein—a disappointing paper ignoring completely the existence of extensive German, British, and American literature. It would seem to this reviewer that anyone dealing with automobile riding comfort would take the time to study R. McFarland's encyclopedic book, "Human problems in air transport design" (McGraw-Hill, 1946) and also refer to the conclusions and recommendations published in many symposia by the Comfort Analysts of Purdue University and the Comfort Committee of the SAE.

The next three papers—"Oscillations of an automobile with different types of independent springing" by R. V. Rotenberg; "Analysis of oscillations of an automobile with considerations of unsprung weights and shock absorbers" by D. V. Gelgat; and "The influence of the suspensions on lateral stability of the automobile" also by R. V. Rotenberg—show a classical bent, inspired by the fundamental studies of S. Timoshenko who, despite the fact that he is an American citizen, is given ample credit for his work. Gelgat's mathematical approach is particularly noteworthy and his simplifying assumptions logical.

Next, a short paper ("The relation of the kinematic configuration of the suspensions to the economic exploitation of the vehicle" by B. S. Falkevitch) explores such items as the permanent and transient cargo shifts and location of the body as related to the dynamics of the vehicle.

I. G. Parheelovsky writes on "The influence of design parameters on the smoothness of the ride; pertinent calculations of automotive suspension." He analyzes the variations of the riding qualities as influenced by the position of the center of gravity; what happens when going through a variety of obstacles; relationships between laboratory experiment and data collected in field work. From this he attempts to calculate the potential energy stored in the suspension system. The author admits

that most of his work is largely speculation, but this reviewer believes that in specific cases the experimental data can be correlated with Parheelovsky's theories, bringing about improvements in selected configurations. In an additionl paper the same author comments on "The rigidity of the independent wheel crank-type suspension," a short treatise exploring the dynamics of this popular General Motors design.

"Calculating the vibration frequency response of an automobile" by P. M. Volkoff is a penetrating analysis of a difficult subject, since the author starts with a general case and shows that general formulas can be derived regardless of the number of modes considered. Matrix calculus is employed terminating in a numerical example relating to the natural frequencies of a specific vehicle. As in some of the other papers, use of Timoshenko's approach (with credit) is made and his notations are used throughout this original paper. Of lesser interest, because of its narrow boundaries, is N. D. Mazolov's "Selection and test of lateral stabilizers on light-weight automobiles" where, by calculation, he is able to select the best compromise design for a specific application. "Methods of testing automobiles for smoothness" by Y. J. Bronstein describes instrument for measuring vibrations, accelerations, and their application in riding-comfort studies. The equipment presented is standard, about 1945 vintage, with no reference to modern strain-gage systems and oscillographic techniques. In the same vein, V. B. Tsimbalin contributes "Methods of duplicating field conditions and the creation of disturbances in the laboratory," a description of test stands and exciters which will excite, no doubt, the automobile but not this reviewer. H. K. Vedeneff gives a "Review of existing suspensions," showing a great number of drawings of elements and assemblies with examples of Russian, American, British, and German designs. Similarly, G. P. Bogdanoff reviews the development of shock absorbers, illustrating his paper with a considerable variety of schematics and drawings.

The editor presents a summary of the papers as the last chapter and concludes that this symposium is only an attempt to provide a guide for the analysis of comfort and stability in automotive vehicles. He ends with a cliché, nevertheless true, stating "that the problem of vehicle suspension contains not only many independent but a multitude of interrelated parameters, hence only applications of theoretical knowledge coupled with intelligent experimentation will produce improved riding qualities."

In brief, despite the cited shortcomings, a valuable contribution to automotive literature.   S. J. Zand, USA

Plates, Disks, Shells Membranes

(See also Revs. 3815, 3818, 3828, 3830, 3853)

3845. Stippes, M., and Beckett, R. E., Symmetrically loaded circular plates, *J. Franklin Inst.* **257,** 6, 465–479, June 1954.

The problem of the circular plate with large deflections, dealt with by von Kármán, Friedrichs and Stoker, Way, and others, is attacked here by using the nonlinear integral equation for the slope rather than the differential equations. The Green function and the slope, as well as the load, can be expanded in a series of Bessel functions which finally lead to an infinite system of nonlinear algebraic equations solvable by truncating after m equations (the magnitude of the error is discussed). The advantage of the method is that the greater part of the numerical work, depending only on the boundary conditions (example treated: the clamped plate with zero radial displacement) and not on the loading, can be done once and for all and that certain properties of the stress distribution can be found by discussing the form of the solution without going into numerical computations.

K. Marguerre, Germany

3846. Müller-Magyari, F., Finite deformations of a thin strip with two free longitudinal borders (in German), *Öst. Ing.-Arch.* **7,** 4, 319–328, 1953.

It has long been known that the center plane of a loaded thin plate forms a developable surface with good approximation in the case of finite deformations. The quality of the approximation depends upon to what extent the inextensibility of the center plane may be assumed. In the present special case of a thin strip with free longitudinal and rigid transverse borders, the application of the pure deflection theory (without extension) is admissible according to which strip takes the form of a developable surface where the initial and final generating lines are determined by the situation of the transverse borders. The two (in general, coupled) ordinary differential equations for determining the deformation under the influence of the load are deduced from the principle of minimum potential energy. Here the method of "quasi-coordinates," used by P. Funk [title source, 1, 2–14] for the rod problem by introduction of variable curvatures, is suitably applied.

As a simple example, the case of loading by a single force and a single moment at the transverse borders is calculated and compared with the result of L. Kirste [Fourth Congress intern. Union f. bridge and above-ground building]. The limiting case of the infinitely long strip (in practice realized for lengths as small as 2.5- to 3-fold the breadth) demonstrates that the center line takes the form of a helical curve, which may be verified by elementary methods without difficulty.   M. Schaefer, Germany

3847. Oravas, G., A method of successive approximations for the solution of continuous shells, *Publ. int. Assn. Bridge struct. Engng.* **13,** 297–308, 1953.

This short method of successive approximations for the solution of spherical shells continuous at their boundary is based on the first-term approximation of asymptotic integration, neglecting Poisson's ratio (reinforced concrete). A short description of the appropriate theory of shells would have considerably improved the value of the paper, since the mere statement of final results will frequently not satisfy the needs of design engineers.

Some terms in the formulas for M_F could be simplified, e.g.: Dead load:

$$\sin \alpha + [\sin \alpha/(1 + \cos \alpha)^2] - \cos \alpha \cot \alpha + [(2 \cot \alpha)/(1 + \cos \alpha)] = 2 \sin \alpha$$

Live load:

$$\sin 2\alpha - 1/2(\cos 2\alpha - 1) \cot \alpha = 3/2 \sin 2\alpha$$

Hydrostatic load on erect shells:

$$2/3 \sin \alpha + 1/3 [\sin \alpha/(1 + \cos \alpha)^2] - [\cos \alpha - (2/(1 + \cos \alpha))] (\cot \alpha/3) = \sin \alpha.$$

M. Hampl, Czechoslovakia

3848. Gruber, E., The right-circular conical membrane of variable wall thickness with any number of elastic ribs (in German), *Publ. int. Assn. Bridge struct. Engng.* **13,** 143–174, 1953.

Author develops a procedure for the computation of any axially symmetrical circular conical membrane of variable wall thickness, stiffened with ribs, and with unsymmetrical loading. The basic equations are obtained in the forms of linear simultaneous differential equations of the second (rigid ribs) or the eighth order (elastic ribs). The derived equations are transformed into relations with three or five members, which is very practicable for calculation.

By means of Fourier series, especially if the variation of wall stiffness is established in analytical form, complicated problems of loading can be treated.

The "collar-work" is the basic system; thereafter the theory of continuous girders of the conical form can be developed in the same mode. [See also AMR **6,** Rev. 857.]

D. P. Rašković, Yugoslavia

3849.   Heller, S. R., Jr., Reinforced circular holes in bending with shear, *J. appl. Mech.* **20,** 2, 279–285, June 1953.

Paper applies work of Reissner and Morduchow [*NACA TN* 1852] to special case of reinforced holes in beams carrying bending moment and shear. Formulas and numerical results are given for the case where the hole diameter is less than one quarter the depth of the beam.   W. S. Hemp, England

3850.   Besseling, J. F., The experimental determination of the effective width of flat plates in the elastic and plastic range (in Dutch), *Nat. LuchtLab. Amsterdam Rap.* S.414, 86 pp., Feb. 1953.

Careful experimental study of the postbuckling behavior of a plane plate subjected to one-way compression. Author discusses the influence of the conditions at the loaded edge and of the side ratio and reviews the literature to determine the best way to support the longitudinal edges. The tests were conducted on aluminum-alloy plates of 1.5-mm thickness and $b = 153$-mm width. Profiles of the buckled plates are shown. The final test result consists of plots of b_{eff}/b vs. (ϵ_k/ϵ), where ϵ_k is the buckling strain and ϵ the apparent (edge) strain under load. It appears that the relation between these two quantities is not much affected by plastic deformations.   W. Flügge, USA

3851.   Botman, M., The experimental determination of the effective width of flat plates in the elastic and plastic range, Part II (in Dutch), *Nat. LuchtLab. Amsterdam Rap.* S.438, 55 pp., Jan. 1954.

This paper is a continuation of an earlier report by Besseling (see preceding review) describing buckling test results of longitudinally compressed rectangular plates. Fourteen 24S-T plates, ranging in thickness from 1.2 mm to 3 mm, with a length in the direction of compression of 700 mm and a width of 459 mm were each subject to a compressive load. The edges of the plates, in the direction of load, were constrained to remain straight during buckling.

Koiter [title source, S.287, 1943] presented an elastic theory for the effective width of an initially flat rectangular plate subject to compression in one direction. Test results from these 14 plates indicate good agreement of the effective width in the plastic range with the prediction of Koiter's theory for the elastic range.

It is to be noted that no measurements were taken of any initial imperfections in the plates, nor were any lateral deflection measurements taken during test. Photographs are presented to show the residual buckling deformations after removal of the load, but no contours of any lobes were measured during any stage of buckling. No mention is made of the ultimate strength concept of a compressed rectangular plate due to von Kármán, Sechler, and Donnell [*Trans. ASME* **54,** 1932].   W. A. Nash, USA

Buckling Problems

(See also Rev. 3850)

3852.   Donnell, L. H., General solution for nonuniform hinged-end columns, *J. appl. Mech.* **21,** 2, 196–197, June 1954.

Simple analytical solution is presented that is applicable to all centrally loaded, pin-ended columns. Essence of method is observation that, if lateral deflection w is expressed in Fourier series and the variable moment of inertia is expressed as $I_0(w/w'')$, the differential equation is automatically satisfied and the buckling load is $P = \pi^2 EI_0/l^2$. Buckling load is thus determined when expansion of moment of inertia is obtained.

G. W. Housner, USA

3853.   Teodosiadis, R., Langhaar, H. L., and Smith, J. O., Inelastic buckling of flat plates, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 105–111, Apr. 1953.

Buckling occurs when the second-order work due to a virtual deflection $W(x,y)$ attains zero value or, alternatively, when the Euler equation has a nonzero solution. Theoretical part of the paper deals with the derivation of the incremental stresses due to W, when the proportional limit is exceeded. Hencky-von Mises stress-strain relations are assumed in which the ratio between deviatory stress and deviatory strain components is secant modulus $G_s = \tau/\gamma$; G_s may be obtained from an ordinary compression stress-strain curve, τ, γ being the corresponding octahedral shearing stress and strain. In the expression of volumetric strain, elastic values of η and G are maintained in order not to cause discrepancies near the proportional limit. Particular behavior during unloading was disregarded.

In the experimental study, aluminum-alloy, simply supported, plates were compressed in the long direction. Theoretical buckling stresses were calculated by means of the authors' theory, assuming $\nu = 1/3$ and deriving G, G_s, and tangent modulus $G_t = d\tau/d\gamma$ from the experimental compression curve of the material. Test results are in very good agreement with the authors' and other deformation-type theories; stress-strain relations of the flow type give too high theoretical buckling stresses.

D. Gentiloni-Silverj, Italy

3854.   Malkina, R. L., Stability of circular arches under periodic axial forces (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **14,** 123–130, 1953.

Stability of circular arches under periodically varying hydrostatic loading is investigated. By applying Galerkin's method, author has shown that instability occurs for certain intervals of the ratio between the period of free vibrations of the arch and the period of load variation. Critical intensity of the dynamical loading can be well under the critical value for statical loads.

D. Radenković, Yugoslavia

3855.   Hoyden, A., and Wilkesmann, F.-W., Numerical analysis of frame buckling by means of a statically interpreted procedure of successive approximations (in German), *Bauingenieur* **28,** 3, 75–80, Mar. 1953.

The buckling load of rods with variable cross-sectional area can be determined by writing the equilibrium equation for any point of the rod for the deformed specimen. This equilibrium equation states that, at any point of the rod, the torsion moment M and the strain v are proportional. The proportionality constant is the required buckling load. According to suggestions of Vianello, first a bending line v_0 (which is statically possible) is assumed and from this the bending moment M_0 is estimated. If, according to Mohr's rule, the bending line v_1 corresponding to M_0 is estimated, this will not agree with v_0. The new bending line v_1 is, however, an improvement compared with v_0. From bending line v_1 we obtain a bending moment M_1 and from this again an improved bending line v_2. This procedure can be repeated until the required accuracy is obtained.

For the first bending line v_0 it is advisable to introduce an average inertia moment J_0. It is then necessary to determine the area of the surface between the straight and the deformed rod. The surface area under the moment line is also estimated. The approximate buckling load is then the ratio of the moment surface area to the bending area.

In the case of statically indeterminate systems, this method is not as convenient, since the iteration calculation becomes very time-consuming. Author suggests, in order to speed up the calculation, to compute only with transverse loads instead of axial loads. The transverse load is estimated through an analogy. One starts from the differential equation for the buckling condition and determines the transverse load which causes the same amount of bending.

The paper presents tables for various possible boundary conditions. An example clarifies the described procedure. It should be mentioned that a doctoral thesis, "Solution of elasticity problems through iteration," by Dr. R. Heckel, Technical University of Graz, treats the same problem in a better way. However, this thesis lacks numerical tables which, in the present paper, greatly facilitate the computation.   E. Friedrich, Germany

Joints and Joining Methods

3856. Donahue, J. E., Analysis of pipe systems with special expansion features, ASME Semi-Ann. Meet., Pittsburgh, Pa., June 1954. Pap. 54—SA-70, 25 pp.

Circular flat-plate and toroidal-shaped expansion joints are frequently used to absorb the dimensional changes of piping systems caused by thermal expansion. A description is given of a variety of types of these devices. These include the use of tie rods to carry hydrostatic thrusts. Appendixes include methods of determining stresses in, and spring constants of, these devices.
I. Vigness, USA

3857. Begeman, M. L., Block, E. H., Jr., and McBee, F. W. Jr., Tension, shear and impact strengths of spot-welded titanium joints, *Welding J.* **32**, 12, 599s–604s, Dec. 1953.

3858. Maloney, J. T., Fusion welding of light-gage alloys, *Welding J.* **32**, 10, 966–969, Oct. 1953.

3859. Koziarski, J., Some considerations on weldability of aluminum alloys, *Welding J.* **32**, 10, 970–984, Oct. 1953.

3860. Smith, H. W., Locating dimensions for tube welding fixtures, *Tool Engr.* **31**, 3, 47–48, Sept. 1953.

3861. Oyler, G. W., and Stout, R. D., Porosity in the welding of carbon steel, *Welding J.* **32**, 9, 454s–460s, Sept. 1953.

3862. Beaton, J. L., and Jonas, P. G., Structural weldment inspection, *Proc. Amer. Soc. civ. Engrs.* **79**, Separ. no. 243, 8 pp., 9 figs., Aug. 1953.

Structures

(See also Revs. 3854, 3855, 3886)

3863. Gattnar, A., and Trysna, F., Timber roof and frame structures [Hölzerne Dach- und Hallenbauten], 6th ed., Berlin, Wilhelm Ernst & Sohn, 1954, xii + 348 pp., 363 figs., 40 tables. DM 39.

This fully revised edition of the well-illustrated, 348-page reference book for the advanced student and practicing architect and engineer in Germany and adjacent countries is the successor to "Timber roof construction" by the late Dr. T. Gesteschi. Its three main parts cover (1) design and computation in general, (2) simple timber roof structures, and (3) engineered timber roof and frame structures.

Design details are given for numerous executed examples of the types of structures under discussion in order to provide ideas and means of comparison for the various designs feasible in solving a particular problem. Unfortunately, many of the presented structures require advanced designers with specialized experience and skilled workmen to execute these designs. Thus, many of these structures may never be executed outside of certain European countries.

No reference is made to developments in the United States, where progress has been made in standardizing designs for timber structures and where such standard designs are available to architects, engineers, and builders who can adapt them to their particular structural requirements. The important field of lightweight, low-pitch trussed rafters, in which development work in the United States has been so successful during the past few years by adapting present technology to well-known design principles, is given no consideration.

Thus it is believed that this book, while doubtlessly appealing to the German specialist, will be of reference value only to the American architect and engineer who is specializing in the field of timber structures and wishes to keep abreast with what is considered up-to-date timber design in Europe.
E. G. Stern, USA

3864. Rothe, A., Frame analysis [Stabstatik], Berlin, Verlag Technik, 1953, 155 pp., 14 figs., 3 tables. DM 24.

Of all areas of advancement in the field of mechanics, the subject of indeterminate analysis has been among the most infertile during the past two decades. The principal reason for this is clear; once the simplifying assumptions of the elementary flexural theory are made, the basic relationships between the redundant quantities are easily established. Within the scope of the theory under consideration, these equations are linear. As a result, practically all recent contributions have concerned themselves exclusively with facilitating the solution of these equations; they have been published mainly because, in their authors' view, the proposed new methods are "easier to handle" or less time-consuming. On the other hand, with a plethora of such "different" methods available or being made available, the underlying identity of all these approaches has often been lost sight of in the literature, so that the reader is left with the impression of being given a choice among genuinely independent lines of attack.

The volume under review constitutes a refreshing exception. Both recognizing and admitting this state of affairs, the author quickly passes over the establishment (without proof) of the fundamental laws and relationships of redundant analysis and proceeds immediately to an elaborate and apparently exhaustive comparison of the various numerical avenues of approach. Various iteration and relaxations procedures, both of the classical "pure" type and their modern "physical" versions (e.g., moment distribution) are presented in elaborate detail, with quantitative comparisons of their rate of convergence and discussions as to its acceleration. The treatment of the subject matter is everywhere coherent and brings out the unity of the alternate methods.

The book is, however, not without shortcomings, some of which are of major magnitude. Apparently faced with the task of compressing the treatment of the subject within less than 200 pages, the author often sacrifices clarity for the sake of brevity. The otherwise admirable organization of the book is somewhat obscured by poor accentuation of chapter headings and an unnecessarily cumbersome nomenclature. Finally, the almost complete concentration of the bibliography on the German literature, to the exclusion of such fundamental contributions as some of the works of Southwell, Temple, Shaw, and Hoff, to name a few, leaves a regrettable gap. On the other hand, the printing is

pleasing and the illustrations, while usually small, are clear.

As a summary and critical analysis of the various methods of solving the equations of classical frame theory, this volume represents, in reviewer's opinion, a valuable addition to the literature.

E. F. Masur, USA

3865. English, J. M., Design of frames by relaxation of yield-hinges, *Proc. Amer. Soc. civ. Engrs.* **79**, Separ. no. 322, 12 pp., Nov. 1953.

Author presents a method for determining the limit (collapse) loads on frames, when failure is due solely to the development of yield hinges. The procedure involves (a) the application of a group of loads, (b) the calculation of any statically compatible system of bending moments, and (c) the successive application of statically compatible corrections aimed at reducing the maximum ratio of computed moment to yield moment (M/M'). The process continues until no further reduction can be effected. At this time there will exist, usually at several points, identical values of M/M'. These points will be the yield hinges which cause collapse.

Justification for this procedure lies partly in the principle that the locations of the collapse yield hinges are independent of the relative stiffnesses of the members. Although this was not adequately proved by the author, it follows directly from the Greenberg-Prager procedure ["Limit design of beams and frames," by H. J. Greenberg and W. Prager, *Trans. Amer. Soc. civ. Engrs.* **117**, p. 447, 1952].

Author closes by showing how a modification of his procedure can be used to disclose the actual order of development of yield-hinges. This method of attack is necessary in cases where maximum load is limited by deflection, rather than by final collapse.

Author's contribution is of great usefulness in highly redundant frames, since it inherently provides a means of solving for the yield hinges. Reviewer finds, however, that the Greenberg-Prager method usually is superior to the author's in instances where the locations of the yield hinges can be determined by inspection. Where there are doubts as to these locations, they frequently can be resolved by the application of the following theorem, set forth by the author: The location of the maximum M/M' in any statically compatible solution is the location of a yield hinge at collapse. (Proof of this also follows from the Greenberg-Prager paper.) After the determination of the location of one or two of the yield hinges, it is often possible to deduce immediately the locations of the remaining ones, and then the Greenberg-Prager method can be applied.

H. Simpson, USA

3866. Michalos, J., Numerical analysis of continuous frames in space, *Proc. Amer. Soc. civ. Engrs.* **79**, Separ. no. 261, 17 pp., Sept. 1953.

A numerical procedure involving successive corrections is developed for determining moments in continuous frames whose members join at arbitrary angles in space. The method is a generalization of the standard moment-distribution technique for plane frames. General formulas are given by which distribution and carry-over factors may be computed for a member having an arbitrary orientation in system of reference axes; the members are assumed straight but not necessarily prismatic. Several worked examples are given.

P. S. Symonds, USA

3867. Killer, J., The economical design of foundations of overhead line towers (in German), *Schweiz. Bauztg.* **72**, 24, 343–350, June 1954; *Proc. Third Inter. Conf. Soil Mech. Foundation Engng.*, Aug. 16–27, 1953, vol. III, 265–276 (in French with English summary).

Author reports new method which uses separate foundation for each leg, relying on shear resistance of soil to uplift instead of dead weight of former single slab foundation. Footing sizes, determined by field loading tests, are interpreted on perimeter shear basis.

T. K. Chaplin, England

3868. Gattnar, A., Reconstruction of a transmitting tower on Feldberg in Taunus (in German), *Bautechnik* **31**, 7, 224–229, July 1954.

This well-illustrated paper describes the design and construction of a 227-ft high transmitting tower with the upper 9 of its 21 stories containing no metal whatsoever to eliminate any electrical interferences.

The timbers of the upper part of the tower were assembled with compressed-wood (compreg) nails and dowels driven into predrilled holes. The nails with round plain shanks were machined to have square heads and needle points. The dowels had slotted ends into which hardwood wedges were driven after tight assembly of the timbers. Bolts and washers of compressed wood were used for joints of a semi-permanent nature. External asbestos-cement wall panels were fastened to the structural members with wood screws and washers of compressed wood.

E. G. Stern, USA

3869. Csonka, P., Torsion of cross-braced pyramidal transmission towers, *Acta Techn. Hung. Budapest* **8**, 1/2, 25–36, 1954.

Paper discusses the torsion of prismatic truncated pyramidal frames of rectangular cross section, assuming that the base is built in a rigid foundation block and that the top, and possibly intermediate sections, are stiffened by horizontal cross bracings, rigid toward coplanar forces. The tower sections between the cross bracings may have different taperings.

The paper follows closely two previous ones by the same author [AMR **7**, Revs. 2462, 2463], discussing the determination of bar forces and the warping of the terminal surfaces of truncated pyramidal frames without cross bracings. On the basis of results obtained there, the present problem is solved by the method of auxiliary forces. The cross-braced sections are cut off the adjacent sections, and releasing forces, at right angle to the terminal surfaces, are introduced as redundant quantities. These forces are shown to obey equations similar to Clapeyron's equations.

Finally, author's method is illustrated by two numerical examples. It is made evident that in cases where the method of bracing is of the same kind and of the same system all along the tower, the bar forces produced by torsion can be computed with a small error by the simple formula contained in the German specifications. On the other hand, if the bracing is different in the individual frame sections, more particularly if it is of opposite system in adjacent sections, the computing method developed in this paper should be employed instead of the routine formulas of the specifications.

From author's summary by Ch. Massonnet, Belgium

3870. Green, W. L., and Gill, S. S., Torsion of a constrained rectangular box section, *Aircr. Engng.* **26**, 300, 34–40, 45, Feb. 1954.

A symmetrical rectangular thin-walled box section with four corner spar flanges was subjected to pure torsion at the free end and the other end was constrained to remain plane. The stresses in the skins, web, and flanges were measured and compared with theoretical calculations based on "linear" and "closely spaced rigid diaphragm" assumptions. The theoretical and the measured values of torsional stiffness are shown. The experimental results show marked effect of buckling of the skin on flange stress.

T. H. Lin, USA

3871. Habel, A., Investigation of cross sections with several layers of prestressed reinforcement, considering the effects of creep (in German), *Beton u. Stahlbeton* **49**, 2, 25–31, Feb. 1954.

A method for considering the effects of creep on the stresses in a composite concrete and steel beam developed by Busemann [*Bauingenieur* 25, 11, 418, 1950] is adopted for prestressed concrete. A cross section symmetrical about vertical axis and loaded with sustained moment in this axis is considered for three types of reinforcement: (1) Several layers of both prestressed and ordinary reinforcement; (2) several layers of prestressed reinforcement; and (3) prestressed reinforcement in one layer. The application of the method is illustrated on three numerical examples. I. M. Viest, USA

3872. Popp, C., A more accurate calculation of the stringers in steel railway bridges [Zur genaueren Berechnung der Fahrbahn-Längsträger stählerner Eisenbahnbrücken] (*Forschungshefte aus dem Gebiete des Stahlbaues*, Heft 10), Berlin, Springer-Verlag, 1954, ix + 62 pp., 26 figs., 8 tables. DM 12.

The continuous stringers are doubly elastically supported by floor beams and truss or girder. The paper gives a method for calculating such systems, the method being easier and quicker to use than classical methods.

With the increase of allowable stresses in railway bridges, improving the stringer calculations has become of importance and the paper, which contains some detailed examples, should be of great value for the designer. A. Selberg, Norway

3873. Gravina, P. B. J., Theory and analysis of suspension bridges (in Portuguese), Escola Politécn. Fac. Arq. Urban. Univ. São Paulo, Brasil, 1951, 178 pp.

This book presents fundamentals of theory and analysis of suspension bridges with any number of spans, with special consideration of most unfavorable distribution of live loads and temperature changes. Chap. 1 deals with fundamentals of the theory and reviews its development with references to the work of Navier, Rankine, A. Ritter, Cadart, W. Ritter, Müller-Breslau, Melan, Krivoshein, Hawranek, Moisseiff, Steinman, Timoshenko, Arnstein, Fritsche, Dischinger, Klöppel, and H. H. Bleich. Chap. 1 also contains derivation of basic differential equations originated by Müller-Breslau and Melan. In chap. 2, cables are closely examined. Author presents his own solution of Müller-Breslau-Melan equations and solution based on Green's function, solution of cable conditions, and derives from resulting relationships equations which are in conformity with Müller-Breslau-Melan equations solved by trigonometrical series. In chap. 3 stiffening trusses are thoroughly discussed, including relationship between stresses and deflections. Chap. 4 contains a great number of tabulated values to simplify the analysis of the Mount Hope Bridge (on 25 pages), designed by D. B. Steinman. Of great value is the extensive bibliography referring to 244 publications. J. J. Polivka, USA

3874. Farquharson, F. B., Aerodynamic stability of suspension bridges. Model investigations which influenced the design of the new Tacoma Narrows bridge, *Univ. Wash. Engng. Exp. Sta. Bull.* 116, part IV, 103 pp., Apr. 1954.

Description is given of the design and erection of a 50-scale model for the new Tacoma Narrows bridge. Model was constructed so that stiffness of suspended structure could be varied as well as torsional stiffness of towers without changing the aerodynamic features of the model. Tests were run on model for ten different configurations of floor and/or stiffening and variations of $V/(Nb)_e$ against β plotted for same. In some cases the effect of diagonal cross-road stays and diagonal tower stays was considered.

Extensive "section-model" tests were used where it was not practical to make tests on the full model, particularly with respect to changes in the shape of the suspended structure. The effect of "spoilers" was studied in these tests as well as the investigation of various modifications of the first proposal for a new bridge. A series of six basic configurations was also studied and "response curves" derived from same. Such tests indicated that catastrophic oscillations could be eliminated provided a slotted roadway slab was used, and a final series of "section-model" tests was run using a slotted deck.

With towers in their stiffest torsional condition, the full model of the final design was tested with two values of truss stiffness. Effectiveness of center diagonal stays, each of which involved a hydraulic damping unit, was considered. Similar tests were run with stiffness of towers reduced. Correlation between section and full-model tests in the final design is discussed and apparent discrepancies partially accounted for.

Brief discussion is given of section-model tests and field observations on the Golden Gate bridge, as well as tests of a typical suspension-bridge section at several values of Reynolds number.

Reviewer believes the principal contribution of this work is as follows: Part 4 (in conjunction with part 3) will serve as a classic in model construction, instrumentation, and operation for those in the future who are interested and concerned with the effect of aerodynamic forces on suspension bridges.

F. L. Castleman, Jr., USA

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 3851, 3865, 3871, 3882, 3902, 3915)

3875. Geiringer, Hilda, Remark on the integration of the stress equations in plane plasticity, "Mémoires sur la mécanique des fluides," Publ. sci. tech. Min. Air, Paris, 85–87, 1954.

Author recalls that radii of curvature of slip lines in plane plastic strain must each satisfy "telegraph equation" $\partial^2 R/\partial\xi\partial\eta = R$ and then shows that quantities X and Y defined by

$$X = x\cos\phi + y\sin\phi \qquad Y = -x\sin\phi + y\cos\phi$$

must also satisfy telegraph equation. P. G. Hodge, Jr., USA

3876. Mathauser, E. E., and Brooks, W. A., Jr., An investigation of the creep lifetime of 75S-T6 aluminum-alloy columns, *NACA TN* 3204, 28 pp., July 1954.

This report presents results on creep tests of 75S-T6 aluminum-alloy columns at elevated temperatures. The tests were made for short time durations and the objective of the program was to obtain procedures for the purpose of predicting column lifetimes. Semiempirical curves based on a previously published column theory are presented for obtaining column lifetimes. These curves are also used to study the effects of varying the applied stress and the out-of-straightness. It was found that small variations in out-of-straightness are of little practical significance, whereas small stress variations have considerable effect on the column lifetime. J. Marin, USA

3877. Handelman, G. H., and Warner, W. H., Loading paths and the incremental strain law, *J. Math. Phys.* **33**, 2, 157–164. July 1954.

This is a mathematical discussion of the differences between incremental strain (plastic flow) laws and total strain (plastic deformation) laws. Suffix notation is used throughout and knowledge of methods of manipulating scalar functions of the components of the stress tensor is required if the arguments used are to be understood.

Authors set out to prove that incremental strain laws of the Prager-Drucker type are in general nonintegrable (i.e., they cannot be found as differentiated forms of suitably designed total strain laws). Allied to this problem are the questions: Under what loading program will a given incremental strain law agree with a given total strain law? Under what conditions will the increment of plastic work as defined for the incremental strain law be independent of the loading path?

Authors show that a given incremental strain law and a given total strain law will, in general, agree exactly only for proportional loading, and a general criterion on the loading function is given which will insure that the plastic work will be independent of the loading path. They suggest that further consideration should be given to the possibility of obtaining estimates of the error committed when a total strain law is used in place of an incremental law, and also of constructing loading functions which will in fact conform to their criterion of plastic-work path independence and still be realistic.   J. M. Alexander, England

3878. Thomas, T. Y., Determination of the plastic yield condition as a variational problem, *Proc. nat. Acad. Sci. Wash.* **40,** 5, 322–331, May 1954.

Author starts from the hypothesis that plastic flow occurs in such a manner as to render stationary some energy integral extended over the region of flow. Without referring to the known variational principles of the mathematical theory of plasticity, which can be interpreted in precisely these terms, he then investigates the effect, on the plastic flow, of the requirement that the integral of some differentiable invariant function ψ of the deviations of stress and velocity strain has a stationary value over the plastic domain. The assumption is introduced that the stress deviation is a differentiable tensor invariant of the deviation of the velocity strain. (In the light of experimental evidence, this assumption of differentiability has been abandoned in several recent investigations of the general structure of the plastic stress-strain relations; see, e.g., papers presented by Budiansky, Dow, Peters, and Shephard at the First U. S. National Congress of Applied Mechanics in 1951 [AMR **6,** Rev. 3064] and Sanders at the Second Congress in 1954 (to appear in Proc.). Koiter [AMR **7,** Rev. 779] has shown that the variational principles of plasticity can be extended to include stress-strain relations of this kind.) When the conditions for the stationary character of the integral of ψ over the plastic region are combined with the equations of equilibrium and the condition of incompressibility, there results an overdetermined system. This overdetermination is found to disappear only if the function ψ reduces to a constant as a function of the components of the deviation of the velocity strain. This result has the nature of a yield condition.
                                                         W. Prager, USA

3879. Capus, J. M., and Cockcroft, M. G., A new technique for investigating surface flow in metal-working processes, *Nature* **173,** 4409, p. 821, May 1954.

3880. Besseling, J. F., A theory of plastic flow for anisotropic hardening in plastic deformation of an initially isotropic material, *Nat.Lucht Lab. Amsterdam Rap.* S.410, 52 pp., Sept. 1953.

Flow theories of plastic deformation, as usually discussed, involved certain assumptions which imply that strain hardening is an isotropic phenomenon. This is inconsistent with the existence of a Bauschinger effect in the torsion test. The present paper contains a theory based on the concept of gradually decreasing elasticity in the plastic range, caused by plastic flow of an increasing portion of the volume. The theory is able to describe the anisotropic behavior of the material in strain hardening;

it is limited to quasi-static loading under isothermal conditions, and to small strains.

The theory is compared with the results of torsion tests on copper tubes and found in far better agreement than is the theory for isotropic work-hardening. In addition, computations for four types of loading processes are performed: (A) Pure tension, followed after unloading by pure shear; (B) pure shear, followed after unloading by pure tension; (C) pure shear followed by tension with constant shear; (D) pure tension followed by shear with constant tension. These are compared with the results of tests of aluminum alloy tubes reported by Marin and Wiseman [AMR **6,** Rev. 1255]. For processes (A) and (B), the anisotropic theory again gives much the best agreement; but for (C) and (D), the divergence of the isotropic theory from the new theory is much less than its divergence from experiment.

                                                    A. D. Topping, USA

3881. Tyabin, N. V., and Pudovkin, M. A., Flow of a visco-plastic dispersion system in a conical diffuser, *Nat. Sci. Found.* tr-209, Feb. 1954; *Dokladi Akad. Nauk SSSR* (*N.S.*) 92, 1, 53–56, Sept. 1953.

Problem is discussed by application of Tyabin's equations [*Kolloid Z.* 13, 1, 1951]. For the solution, the following assumptions are made: flow is stationary and slow and directed along radii vectors; no external forces exist.   B. Gross, Brazil

Failure, Mechanics of Solid State

3882. Stroh, A. N., The formation of cracks as a result of plastic flow, *Proc. roy. Soc. Lond.* (*A*) 223, 1154, 404–414, May 1954.

Author considers how the stress concentration near the piled-up group of n positive edge dislocations at the end of a slip line affects the crack development. The author assumes the following: Only the stress component which is normal to the plane is participating in the development of a crack; locally the stress approaches the time fracture stress; and the author requires the crack formation be accompanied by a decrease in the system's energy. With the leading dislocation locked in position, the equilibrium positions of the free dislocations are found by zeros of the derivative of the nth Laguerre polynomial. The value of the normal stress and its direction are obtained. These stress equations together with the expression for the energy of the crack provide a condition for initiation of a crack. The length of a crack does not enter as a variable into this condition which states that the product of the number of dislocations and the applied stress is greater than seven tenths of the modulus of rigidity. When this is evaluated for a work-hardened metal such as copper, then it indicates that a crack should be formed near a piled-up group of about 1000 dislocations. Author presents the stress system for cases when the crack is normal or oblique to the slip plane.

The length of the crack, cut-off distance, and equilibrium crack length are variables in the expression for the elastic energy of the crack, independent of the angle between the crack and the slip plane. The crack length is determined from the condition of minimum total energy, which is the elastic energy plus the surface energy. The difference between the energy of the original piled-up group dislocations provides the decrease in energy due to the formation of a crack. From this the equilibrium length of a crack is found to be (approximately) equal to the product of the square of the number of the dislocations and the unit Burgers vector.

In conclusion, author briefly discusses the applicability of the above conditions with mention of Griffith and Cottrell mechanism.

V. A. Valey, USA

3883. McKinsey, C. R., Effect of low-temperature stress-relieving on stress-corrosion cracking, *Welding J.* **33,** 4, 161s–166s, Apr. 1954.

Tests made under laboratory conditions showed that residual welding stresses were sufficiently high to cause stress-corrosion cracking in some steels when exposed to a mixed nitrate solution. Both rimmed and killed steels were shown to be susceptible, and the carbon content appeared to have some effect. Controlled low-temperature stress relieving was found to be effective in protecting welded plates from stress-corrosion cracking. The laboratory tests were supplemented by field tests in which specimens were immersed in a large storage tank containing 85% ammonium-nitrate solution for a period of 10 months. Severe cracking took place in the as-welded plates but not in the low-temperature stress-relieved plates.

From author's summary by G. V. Smith, USA

3884. Irwin, G. R., and Kies, J. A., Critical energy rate analysis of fracture strength, *Welding J.* **33,** 4, 193s–198s, Apr. 1954.

Paper presents a relatively simple mechanical concept of fracture as a process of crack propagation, based on a consideration of instability: such instability is reached when rate of strain-energy release accompanying crack extension equals rate of "fracture-work" done in the course of this process. When the rate of "fracture-work" is considerably lower, material shatters rather than fractures along a definite plane.

Attempt is made to estimate order of magnitude of critical rate of fracture-work for insetting instability from test results on notched steel plate.   A. M. Freudenthal, USA

3885. Rodman, C. J., and Shollenberger, F. J., Flexure and fracture of vitreous enameled steel strips, *Bull. Amer. ceram. Soc.,* 105–107, Apr. 1954.

An investigation has been made of the strength of varying steel gage thicknesses as used in the manufacture of steel sanitary ware and the accompanying effect of enamel coatings thereon. A new sensitive apparatus has been developed to determine the progressively increasing loads (stress) and the corresponding deflections (strain) of enameling grade steel used. In the case of porcelain enamel on steel, the stress-strain curves show that the added strength is not in proportion to the thickness of the enamel but due to the bonding of the enamel to steel; the strength has increased approximately as the cube of the sum of the steel thickness and one half the enamel thickness. From authors' summary

3886. Chamecki, S., Calculation of cross-reinforced concrete slabs in the vicinity of failure |Cálculo, no regime de ruptura, das lajes de concreto armadas em cruz|, Curitiba, Paraná, Brasil, Editora Guaíra Limitado, 1948, 106 pp.

Professor Chamecki's book is a good and concise presentation of yield-line theory, a branch of the plastic theory of concrete design developed mainly in the past two decades by K. W. Johansen.

In the first chapter, author states general considerations about ultimate load design based on failure load of structures. Chap. 2 is devoted to the theory of rupture of cross-reinforced slabs, both isotropic and orthotropic, and of arbitrary shape, load, and edge conditions. Slabs are assumed to be divided, in the failure stage, into several parts, limited by yield lines. A yield line is like a yield hinge or plastic hinge, used in the plastic analysis of indeterminate structures; it is a line of maximum moment, where the steel has reached the yield point. As the different parts of the slab are considered plane, the yield lines are straight. The

ultimate load is reached when the yield lines have spread into the whole slab, forming the yield-line pattern. All deformations of the slab may be considered as rotations about the hinge lines and about the free supports. The acting shearing forces are replaced by a statically equivalent pair of forces, applied at the intersections of the hinge lines. The determination of the yield-line pattern, and the corresponding ultimate load, may be made by using static equations alone, or the principle of virtual work, or both together.

In chap. 3, author develops a set of formulas for the ultimate design of concrete sections under flexure. These formulas are based upon the Brazilian building code and upon the theories of the Brazilian Professor T. Van Langedonck. In chap. 4 the yield-line theory is used to derive ultimate load equations for square and rectangular slabs, with different support conditions and various types of loads.

The fifth chapter is devoted to comparisons with test results. The yield-line theory is applied to data pertaining to the tests of C. Bach, C. Bach and O. Graf, W. Gheler, and A. Ames. A fairly good agreement is found between theory and experimental results. In the sixth and last chapter a brief discussion is presented about criteria for selecting a correct value of the safety factor for slab design. A distinction is made between margin of safety according to the uncertainties in the strength of steel and concrete, and margin of safety regarding other items, such as applied load, reliability of calculus procedure, accuracy of the building methods, seriousness of the failure, etc. It is proposed to assume at failure that the steel is strained at the yield point and the concrete at $0.9 f_c'$ (compressive strength of 6×12-in. concrete cylinders). A load factor of 1.7 is also proposed. The book closes with tables for practical applications of the yield-line theory for rectangular slabs.

Reviewer makes the following comments: Despite the fact that it has been developed as a separate branch, the yield-line theory is, on the whole, similar to the theory of plastic design of indeterminate concrete structures. It is a practical and powerful instrument of concrete slab design, not confined to particular problems but capable of solving the more complex cases, with a single criterion and with a minimum of mathematical effort, since the analysis of slabs is reduced to geometry and algebra. Professor Chamecki's book deserves the particular attention of all engineers interested in concrete design because it is one of the few books presenting this currently important theory.

C. A. Sciammarella, Argentina

Material Test Techniques

(See also Revs. 3876, 3897, 3900, 3901)

3887. Thompson, R. L., Correlation of gamma radiography and Magnaflux indications in the inspection of large cast-steel connecting rods, *ASTM Bull.* no. 197, 58–59, Apr. 1954.

The two methods for nondestructive testing may complement one another, as shown by an example of shrinkage cracking.

O. Ruediger, Germany

3888. Anonymous, Field soniscope tests of concrete. Report no. 1. 1953 Tests, *Wways. Exp. Sta. tech. Memo.* 6–383, 18 pp., Apr. 1954.

3889. Roesli, A., Loewer, A. C., and Eney, W. J., Machine to apply repeated loads to large flexural members, *ASTM Bull.* no. 196, 50–53, Feb. 1954.

A testing machine that simulates the passage of trucks at various speeds over bridge members is described.

From authors' summary

3890. Laborde, A., Reciprocal compensation of statical tensions and relative extensions in fatigue tests by repeated tractions (in French), *C. R. Acad. Sci. Paris* **237**, 20, 1211–1213, Nov. 1953.

Fatigue testing with statical tensions of yarns showed that a linear correlation exists between the preload stress and the superimposed strain, if the alteration number remains constant until failure. In case of increased preload, the strain decreases if the same alteration number leads to failure. The proportionality constant is experimentally determined.   L. Föppl, Germany

Mechanical Properties of Specific Materials

(See also Revs. 3859, 3861, 3881, 3903, 4016, 4038)

3891. Jones, B., and Owen-Barnett, R. A., The strain ageing of mild steel. A critical investigation of the ageing of mild-steel strip after temper-rolling, *J. Iron Steel Inst. Lond.* **177**, 2, 209–220, June 1954.

In the production of steel strip for cold pressing and drawing, the annealed material is temper-rolled to prevent formation of stretcher strains. Due to aging, the yield points may reappear. Authors have investigated the strain aging of eight different rimming and killed steel of basic open-hearth and basic Bessemer origin after temper-rolling. Strain aging was studied from autographic tension curves. Unexpected results were found on artificial aging of pure iron at 100, 200, and 300 C where there was an increase in yield stress and a return of a yield point at each temperature. Differences between artificial and natural aging are smaller in Bessemer than open-hearth steel. Artificial aging at temperatures of 100–250 C gives high values of yield stress; and for the killed steels a return of the yield point was shown at 200–250 C. The yield point of vanadium-treated rimming steel did not reappear after artificial aging. Aging treatments of temper-rolled steels for 1 day at 75 C are the same as those found by natural aging for 1–3 years. Storage at low temperatures of 0 and minus 15 C showed a marked retardation in the aging rate of open-hearth and Bessemer steels, with particular stabilization at minus 15 C for several months, whereas aluminum killed steel was further stabilized. Authors assert that the dislocation theory best explains their results when the residual stresses are considered.   H. Majors, Jr., USA

3892. Yokobori, T., Delayed yield and strain rate and temperature dependence of yield point in iron, *J. appl. Phys.* **25**, 5, 593–594, May 1954.

A unified explanation of delayed yield and of strain rate and temperature dependence of yield point in iron was attempted on the basis of the Cottrell locking theory, taking internal stress into account. The energy of a dislocation required to fit existing data is small by an order of magnitude compared with the value theoretically estimated by Mott and Nabarro. The distance, calculated from the value of internal stress, between dislocations assembled at a grain boundary is of a reasonable order of magnitude. It is suggested that the mechanism of yielding may change from Cottrell type to Mott-Nabarro or Frank-Read type when applied stress falls below some limiting value.

From author's summary

3893. Majors, H., Jr., Dynamic properties of nodular cast iron. Part 2—size effect, *Trans. ASME* **76**, 2, 205–216, Feb. 1954.

Paper contains reversed bending fatigue data. The effects of the size of the specimen and also the size of the casting from which the specimens were made were studied. The following statements from the conclusions are pertinent: (a) "For unnotched specimens in the annealed or as-cast condition, there is no significant size effect on the endurance limit for test sections ranging from 1.25 in. to 0.30 in. diam when specimens are removed from a 2-in. diam casting." (b) "Notched fatigue specimens showed a size effect in both the annealed and as-cast" condition for specimens cut from 2-in.-diam castings. (c) "The endurance curves were identical for specimens removed from 4-in. and 2-in.-diam castings."   E. A. Davis, USA

3894. Reininger, H., Corrosion prevention by means of sprayed metal coatings, *Werkstoffe u. Korr.* **4**, 5, 156–172, 1953.

Article is a good compilation of already well-known features of the problems and possibilities in metal coating by use of spray methods. More than 80 references are listed.

R. Nilson, Sweden

3895. Paasche, O. G., and Killin, A. J., Fabrication of a zirconium-lined reaction vessel, *Welding J.* **33**, 2, 115–118, Feb. 1954.

3896. Esenwein, P., Determination of cement content in concrete structures after erection (in German), *Schweiz. Arch.* **19**, 9, 279–283, Sept. 1953.

Paper reviews granulometric and chemical analysis methods for determination of amount of Portland cement in concrete samples on the premise that, in cases where a structural failure has occurred, such failure is not always traceable to design error, frost action, or chemical decomposition, and cement concrete probably is the only remaining factor. By means of tests upon laboratory specimens, author establishes the accuracy of the chemical analysis method.   J. E. Goldberg, USA

3897. Anonymous, Permeability and triaxial tests of lean mass concrete, *Wwys. Exp. Sta. tech. Memo.* no. 6–380, 87 pp., Mar. 1954.

Permeability tests and triaxial loading tests were conducted on concrete cylinders of various mixture properties. High-pressure permeability tests of laboratory specimens and low-pressure permeability tests of cores from existing structures are reported. Carlson strain gages placed near longitudinal axis were used to measure axial strains in unsaturated and saturated specimens loaded triaxially. Appendix contains discussion of permeability, pore pressure, and uplift problems in gravity dams, together with suggestions for further research.   W. D. Jordan, USA

3898. Garve, T. W., Clay testing of structural clay materials, *Bull. Amer. ceram. Soc.* **33**, 3, 75–78, Mar. 1954.

3899. Czechowicz, J., The influence of the specific gravity of pine wood (Pinus Sivestris) on the parallel-to-grain compressive strength (in Polish), *Zeszyty Nauk. Politech. Warszawskeij. Budown.* no. 3, 1954.

The first part of the work contains a review of Polish and foreign data concerning the problem. General comments on the topic are included. The second part constitutes a report on the investigation comprising 3022 results, carried out by the author on small specimens of pine wood of dimensions $2 \times 2 \times 3$ cm. All the data concerning the specific gravity γ and the strength R have been reduced to the level of 15% moisture content. The question has been worked out in detail using mathematical statistics. As the first approximation, the exponential function $R = 860 \gamma^{1.1}$ was used. The second step concerned the analysis of the straight line $R = 859 \gamma - 42$, the correlation coefficient being

0.80. The differences calculated from the afore-mentioned formulas in the area of most frequent values of γ (between 0.40 and 0.70) were quite insignificant. As they did not exceed 0.5%, the straight-line correlation was assumed as the best one from the practical point of view. On the basis of the straight-line formula and applying the well-known formulas for the reduction of γ and R at a given moisture content to the level of 15% moisture content, a graph was constructed. From this graph the values of strength for the given specific gravity and moisture content of the specimens can be read.   From author's summary

3900. Spinner, S., Elastic moduli of glasses by a dynamic method, *J. Amer. ceram. Soc.* **37**, 5, 229–234, May 1954.

The elastic moduli and speed of sound of 23 optical glasses, a series of Na_2O, CaO, SiO_2, and B_2O_3 glasses, and some specimens of fused silica were measured by a dynamic method. Each specimen, in the shape of a prismatic bar, was vibrated in four different ways: longitudinally, flexurally on the wide side, flexurally on the thin side, and torsionally. Good agreement was found on Young's modulus as determined by the first three methods. The torsional mode was used to obtain the shear modulus. Statically and dynamically determined values of Young's modulus for six sample glasses also showed good agreement.

From author's summary

3901. Baker, A. G., Hillier, K. W., and Woodward, R. H., An analysis of the results of a visual test of textile yarn, *Appl. Statistics* **3**, 1, 12–18, Mar. 1954.

By analyzing the results of a specially planned set of observations, the authors are able to show that a partially subjective test of yarn quality can give reliable results. The errors are estimated. This article also presents an interesting example of the use of transformations of the observed variable.

From authors' summary

3902. Bartenev, G. M., Lepetov, V. A., and Novikov, V. I., Static compression of flat, annular rubber gaskets (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **93**, 1, 15–18, Nov. 1953.

Tests on three types of rubber show that previous empirical relations [AMR **6**, Rev. 1917; **7**, Rev. 2877] hold also for ring shape. At high carbon content, the parameter a (measured with surfaces dry) decreases from 1.0 to 0.5.

William Fuller Brown, Jr., USA

Mechanics of Forming and Cutting

(See also Revs. 3891, 4068)

✎3903. **Bucksch, W., and Briefs, H., Compression molds in the plastics industry [Presswerkzeuge in der Kunststofftechnik],** Berlin, Springer-Verlag, 1953, vii + 152 pp., 156 figs. DM 25.50.

Reviewer found this book to be the most complete text on design of molds for thermosetting plastics to date. All phases of both compression and transfer molds are discussed, from simplest single cavity to most complex multicavity mold. All points are thoroughly illustrated by excellent drawings and photographs. Interesting section on standardization of molds has been included. Manufacture of molds and mold steels also has been covered.   F. J. Mehringer, USA

3904. Watts, A. B., and Ford, H., An experimental investigation of the yielding of strip between smooth dies, *Instn. mech. Engrs. Proc. (B)* **1B**, 10, 448–453, 1952/1953.

Paper reports results of experiments on indentation of high-

conductivity copper strip and brass plate between narrow dies placed normal to the length of the strip and overhanging at the ends. Tests approximate to plane strain conditions. Strip-thickness to die-breadth (t/b) ratios ranging from 19.20 to 0.33 are considered. Theories due to Hill (1947) and Green (1951) [AMR **5**, Rev. 104] give plane strain solutions for ratios zero to infinity. Experiments show a remarkable correlation with theory, particularly for $t/b < 1$.

Reviewer believes the paper will be of interest to those engaged on rolling theory and design. To the theoretical worker the most striking feature is the excellent agreement between the experiments using work-hardening elastic-plastic materials and theory for a plastic-rigid nonhardening solid.

J. F. W. Bishop, Scotland

3905. Kellermann, R., and Alsen, K., Energy exchange in cold upsetting in a double press (in German), *Stahl. u. Eisen* **73**, 22, 1410–1418, Oct. 1953.

The consumption of energy during a two-stage cold heading operation on an upsetter is studied by means of calorimetric measurements. One-, two-, and a few three-stage tests were conducted. The various sources of error were studied. Additional comparison tests were conducted at slow speeds on a testing machine.

The rate of deformation was found to have an effect upon the energy consumption. At intermediate deformation rates, the energy consumption was less than at low rates; however, at maximum rates tested, the energy consumption was greater than at the lowest rates. This is explained by assuming that the flow stress tends to decrease with temperature and increase with strain rate. At intermediate speeds, the temperature effect predominates and, at high speeds, the strain-rate effect predominates. Quantitative values for the coefficients due to temperature and strain rate were not obtained.

The testing-machine results were found to be in general agreement with the semi-empirical formulas

$$P/F = cf^n[1 + 2/3\mu(r_x/h_x)]$$

$$A/V = c[f^n/(n+1)]\,[f + 4/9\mu(r_x/h_x)]$$

The symbols used are not clearly defined, but are believed to have the following meaning: P applied force, F cross section, A work, V volume, f compressive strain, r_x radius of head, h height of head, μ coefficient of friction (a value of 0.2 was found to be applicable), c and n constants depending upon the empirical equation $k_f = cf^n$ for the stress-strain relation, where k_f is the stress at strain f.

W. Schroeder, USA

3906. Hessenberg, W. C. F., and Jenkins, W. N., The effects of screw and speed setting changes on gauge, speed and tension in tandem mills, "Research Correspondence," Suppl. to *Research, Lond.* **7**, 8, S45, Aug. 1954.

3907. Svahn, O., Deep-drawing properties of sheet steel, *J. Iron Steel Inst. Lond.* **177**, 1, 129–142, May 1954.

A series of tests were conducted in an attempt to find a method for grading sheet steel to be used in deep-drawing operations. It was found, upon statistically examining the experimental data which had been accumulated, that the results obtained from tear length, expanding (Siebel and Pomp) or depression (Erichsen) tests were not too useful. Only deep-drawing tests provided satisfactory information.

A number of deep-drawing experiments on materials having very different characteristic were then discussed in which the effect of tool size, edge radius, drawing speed, clearance, blank-

holder pressure, surface finish, and lubrication were considered.

The Research Committee, of which the author is a member, intends to propose a standard procedure for determining the drawing quality of sheet steel based on the two deep-drawing tests described in this paper.   B. W. Shaffer, USA

3908. Chung, S. Y., and Swift, H. W., An experimental investigation into the redrawing of cylindrical shells, *Instn. mech. Engrs. Proc. (B)* **1B,** 10, 437–447, 1952/1953.

Paper extends the experimental investigations reported previously [AMR **6,** Rev. 515]. An account is given of the forces, work, and strains involved in the redrawing process. Brass, mild steel, and aluminum cups of 4-in. diam were used. Authors examine direct and reverse methods of drawing. Effects of first-stage drawing ratio, heat treatment, punch profile radius, first-stage punch-die clearance, redrawing radio, blank thickness, material, and temper are discussed. Conclusions summarize and interpret the results for the design engineer.

Reviewer believes this to be a paper of considerable interest and importance for the designer. The data provide a useful addition to that in the review quoted for theoretical work on this problem.   J. F. W. Bishop, Scotland

3909. Wallquist, G., Calculation of roll pressure and energy consumption in hot-rolling, *J. Iron Steel Inst. Lond.* **177,** 1, 142–158, May 1954.

A series of tests were conducted on 16 different steels in an attempt to clarify the influence of steel composition, temperature, reduction, and material thickness on roll pressure, energy consumption, and material deformation. Part of the experimental results are summarized graphically. The remainder will be reported at a later date.   B. W. Shaffer, USA

3910. Meister, K., Novel design of drive with variable speed control of a wire-rolling mill (in German), *Stahl u. Eisen* **74,** 3, 151–154, Jan. 1954.

3911. Colwell, L. V., Predicting the angle of chip flow for single-point cutting tools, *Trans. ASME* **76,** 2, 199–203, Feb. 1954.

A correlation of size of cut, tool geometry, and chip flow. It is shown that side rake angle and the nose radius of single-point tools influence tool life to a considerable degree.
                                               'A. O. Schmidt, USA

3912. Lindbeck, S. L., To machine radioactive materials, *Amer. Machinist* 98, 8, 166–167, Apr. 1954.

3913. Henriksen, E. K., Balanced design will fit the chip breaker to the job, Special Report no. 360, *Amer. Machinist* **98,** 9, 116–124, Apr. 1954.

3914. Loewen, E. G., and Shaw, M. C., On the analysis of cutting-tool temperatures, *Trans. ASME* **76,** 2, 217–225, Feb. 1954.

Authors' analysis is based on Piispanen's "card-deck" model of metal cutting, so that reviewer's theory about the partition of heat between two contacting and moving surfaces, between which the heat source is located, is made to apply to the shear plane at the root of the chip. Utilizing the same theory for the frictional heat at the tool-chip interface, authors find an expression for the mean temperature rise at that interface by superimposing the temperature rise caused by the shearing heat on that caused by the frictional heat.

By introducing some approximations, which appear quite reasonable, the expression found was simplified to an extent where it can be handled with ease and where the relative importance of the different variables can be judged in a synoptical manner. The experimental verification proved satisfactory.

Together with the discussions, which cover previous theories by others as well, and with authors' closure, paper constitutes an enlightening summary of present state of knowledge about problem in hand.   H. Blok, Holland

3915. Lee, E. H., A plastic-flow problem arising in the theory of discontinuous machining, *Trans. ASME* 76, 2, 189–193, Feb. 1954.

A set of slip-line field solutions is presented which satisfies the stress and velocity boundary conditions during the first stage in the formation of a discontinuous chip. It is during this stage that the fracture surface in front of the tool deforms whi'e the free surface of the workpiece remains undisturbed. The range of applicability of each of the solutions presented is also discussed.

The author found that the apparent shear angle during the first stage of discontinuous chip formation is insensitive to variations in the coefficient of friction at the tool-chip interface.
                                               B. W. Shaffer, USA

3916. Archibald, F. R., Analysis of the stresses in a cutting edge, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-160, 16 pp.

Analysis is made of the elastic stresses which may exist within a cutting tool during machining, important in understanding tool wear and failure. Simplified assumptions are made as to the distribution of load on the tool face and its variation with rake angle and other quantities. Equations for the stresses are then derived from the applicable stress function in the conventional manner and the coefficients evaluated from the assumed boundary conditions. Values of the stresses are computed for the point of the cutting tool, assuming this to be the most highly stressed region. Values are very high, with principal stresses ranging from −200,000 psi to 1,000,000 psi or more as chip friction and rake angle are varied over the possible range. Such extreme upper values are presumably due to the simplified boundary conditions assumed, and some consideration is given to the effect of modifying these.   M. E. Merchant, USA

Hydraulics; Cavitation; Transport

(See also Revs. 3935, 3936, 3943, 3969, 3997, 4080, 4096)

3917. King, H. W., Handbook of hydraulics, 4th ed. (revised by Brater, E. F.), New York, Toronto, London, McGraw-Hill Book Co., Inc., 1954, xvii + 463 pp. $8.

This handbook should prove particularly useful to the engineer. Owing to many tables and curves concerning the diverse fields of hydraulics, some calculations frequent in hydraulics can be considerably shortened. Useful information related to hydrostatics, flows through orifices, gates and tubes, to spillways, pipes, and open canals is completed by tables of numeric values.

Regarding the tables showing the corresponding values for various systems of units, it is to be regretted that the metric system has not been given a sufficiently important place in this handbook.   L. Escande, France

3918. Doland, J. J., Hydro power engineering, New York, The Ronald Press Co., 1954, vi + 209 pp. $7.50.

This textbook has been prepared for civil-engineering students at senior or graduate level. The reader is assumed to have an

understanding of engineering fundamentals and experience in equipment design (civil, mechanical, and electrical engineering) in other courses. The book has been kept small in size on the basis that the instructor will refer to current technical papers for reference material regarding modern advancements and improvements.

Eight chapters are devoted to an introduction to water-power developments; definitions and descriptions for water-power studies with essential equipment formulas; power available and load determinations; classification, selection, and specifications for hydraulic turbines, including runaway speed and cavitation; power-house considerations; appurtenances (dams, controls, surge tanks, air vents, etc.); economic aspects; combined hydrosteam performance. About 50 problems arranged by chapters are presented at the end of the book, ranging in difficulty from simple substitution of numbers into equations to a complete preliminary design report.

This book is a quantitative introduction to preliminary design phases of water-power engineering and is valuable for the practicing engineer or advanced engineering student from any field that may be interested in water power. It briefly presents the state of the art about items required in water-power-plant selection, preliminary design, and specifications. The text is useful and easy to follow, but outside references from current technical literature are necessary to study recent practice. Current subjects would include recent hydro-plant installations and performance, a discussion of pumped storage hydro plants (limited in book to a problem statement), and the possible importance of interconnected hydro and atomic power plants (not mentioned in book).

The author has accomplished his purpose in an admirable manner, but, in the opinion of the reviewer, it is unfortunate that a closer development, following directly from fundamentals, was not made in order to clarify ideas about such items as speed of rotation in specific speed and that efficiency of impulse wheels is necessarily lower for increased number of jets.

R. G. Folsom, USA

3919. Gaden, D., Operation of a hydroelectric unit coupled to an infinite network in the presence of automatic speed control and water-hammer phenomena (in French), *Bull. tech. Suisse Rom.* **80**, 2, 3; 17–26, 29–36; Jan., Feb. 1954.

The article follows from a former one of the same author ["Recherche d'une condition de stabilité," Work of the century of the Polytechnique School of University of Lausanne, 1953] concerning the influence of the water-hammer phenomenon in water turbines on the stability of electric generators when they are connected to the network. The formula for the magnitude of the damper effect needed for stability is given and, on basis of examples, author shows that, using incomplete dampers, the conditions of stability can be aggravated at low charge. It follows from these examples, too, that the moment of the damper brought about by a slip of 1% is greater than 5–9% of the moment at full load. Especially for generators coupled with low head turbines, these circumstances must be taken into consideration, as the selectivity of the vibration system in this case is small.

M. Nechleba, Czechoslovakia

3920. Lamont, P. A., A review of pipe-friction data and formulae, with a proposed set of exponential formulae based on the theory of roughness, *Proc. Instn. civ. Engrs.* **3**, part 3, 248–275, 1 plate, Apr. 1954.

Some 200 pipe-friction data for old and new pipe are compared, with good agreement, with friction factor curves based on Prandtl-von Kármán-Nikuradse-Colebrook analysis, which the

author calls the "theory of roughness." Other pipe-friction formulas are discussed. The author also devises a set of power-law formulas to fit the data. Very little is said concerning analysis and experiments relating to the transition region between laminar and semiturbulent flow, which the author labels the "unstable zone."

L. Talbot, USA

3921. Gray, C. A. M., Analysis of water hammer by characteristics, *Proc. Amer. Soc. civ. Engrs.* **79**, Separ. no. 274, 14 pp., Sept. 1953.

Author extends the well-known method of Snyder-Bergeron [see Snyder, *Schweiz. Bauztg.,* 1929, and *Wasserkraft u. Wasserwirtschaft,* 1932 and 1935; Bergeron, *Rev. gén. Hydr.,* 1935, and *Tech. Mod.* 1935 and 1936] that he ascribes to W. Angus and G. Rich. Purpose of the extension is to consider effects of friction in cases of practical importance; consequently, construction of the Snyder-Bergeron method, explained also in some hydraulical treatises [see, e.g., C. Jaeger, "Technische Hydraulik," Basel, 1949], receive little modification.

A sufficient approximation is often obtained by considering friction as a linear function of the velocity.

G. Supino, Italy

3922. Tsubaki, T., Kawasumi, T., and Yasutomi, T., On the influences of sand ripples upon the sediment transport in open channels, *Rep. Res. Inst. appl. Mech.* **2**, 8, 241–256, Dec. 1953.

Experiments were conducted in five rectangular-section irrigation canals to determine effects of sand ripples on channel roughness and bed-load transport. The effect of ripple formation in channel bed is of considerable importance in the hydraulics of alluvial rivers and canals. Canals used were 5 km long, between 0.8 and 3.8 m wide, 0.0008 to 0.0017 m/m slope, with 30-cm deposit of bed material. Sediment grain size varied between 0.2 and 10 mm, with median between 1 and 2.5 mm. In addition to velocity distribution, flow, and slope, the length, height velocity of progression, and rate of sediment transport of the sand ripples were measured. The last was determined by a boxlike trap inserted in the bed and operated when stability was reattained. Data are given on scale of the sand ripple, velocity distribution, rate of bed-load transport. Comparisons are made with the work of H. A. Einstein and others. The investigators conclude that, because of the wide variety of conditions which may be encountered in rivers and artificial channels, much more extensive studies are needed to fully describe the character of sand ripples in terms of the hydraulic conditions of flow and bed-material characteristics.

M. C. Boyer, USA

3923. Dementiev, M. A., Hydraulic efficiency of silt transporters (in Russian), *Gidrotekh. Stroit.* **22**, 9, 3–6, Sept. 1953.

Article deals with silt transportation in dredge pipes. Total energy of the mixture is represented as a function of dimensionless value $\Pi = (c/\Delta + c) \cdot (Q/g^{1/2} R^{3/2})$, similar to Froude number, where $c = \Delta Q_s/Q$, Δ is specific gravity of sand, Q_s is sand discharge, R hydraulic radius. Results of 25 laboratory tests with different samples of sand show a parabolic relationship of 2.2 to 2.8 power.

S. Kolupaila, USA

3924. Fil'chakov, P. F., and Panchishin, V. I., Apparatus for filtration study based on electric analogy principle (in Russian), *Gidrotekh. Stroit.* **22**, 9, 39–40, Sept. 1953.

Electro-hydrodynamic analogy method (EHDA), originated by N. N. Pavlovsky in 1918, was many times improved and is widely known. Authors use especially impregnated paper as a conducting medium. Different soil permeability can be repre-

sented by zones of paper with different resistance, varying million times. Flow net can be easily drawn on the same paper with colored pencils.   S. Kolupaila, USA

3925. Verigin, N. N., Interaction of wells in transperipheral flooding of petroleum deposits (in Russian), *Dokladi Akad. Nauk SSSR* (*N.S.*) **91**, 4, 753–756, Aug. 1953.

Paper considers the problem of flow of liquid in a pervious earth stratum of constant thickness in the vicinity of two sets of wells: the oil wells through which the oil is pumped out, and the water wells, lying outside of the oil region, through which the water is pumped in for the purpose of displacing the oil. The in- and out-flow wells are equal in number and are uniformly spaced on two concentric circumferences. Constant known rates of flow are attributed to all wells, although the rates of inflow are different from the rates of outflow. No distinction is made between the two liquids with regard to their viscosities and densities. The paper presents without derivation a formula for the pressure of liquid at any point in the region as a function of rates of in- and outflow, location in plan, and the time.

A. Hrennikoff, Canada

3926. Golubeva, O. V., Certain problems for the laminar filtration of fluids in heterogeneous twisted layers of variable thickness (in Russian), *Prikl. Mat. Mekh.* **17**, 4, 485–490, July-Aug. 1953. [Reviewer's translation is filed with Scientific Translations Division, Library of Congress.]

Paper is devoted to work of tunnels and boreholes in water-bearing layers. Navier-Stokes equations of motion of a viscous incompressible fluid are linearized, inertia terms are neglected, problem is reduced to two-dimensional, and stream function is introduced. Isothermic coordinate system is chosen on lower surface of layer as basis. General formula is developed for filtration along coordinate lines which is applied to five examples. First case is of tunnel along a coordinate axis in layer of constant thickness and permeability; second is case of layer of constant thickness along arbitrary cylindrical surface, with tunnel along a coordinate curve; third is tunnel along a closed coordinate line on a layer, of constant thickness and permeability, in a plane; fourth is of tunnel along a coordinate line in a layer of variable thickness and constant permeability; fifth is of borehole in a dome-shaped surface when the layer thickness and permeability are variable.   M. D. Friedman, USA

3927. Dahme, A., Calculation of the specific inside surface of porous bodies (in German), *Ing.-Arch.* **21**, 5/6, 346–351, 1953.

Author develops from pore-size distributions the parameters for obtaining the specific surface of the pores. He assumes two types of distribution: normal and logarithmic. In both cases, the median is used rather than the respective means of the distributions in the ratios of the second and third moment integrals of surface and volume. Results of these ratios are in graph form to facilitate computations. Method proposed does not seem to be as simple or as effective as that used by Hatch and Choate [*J. Franklin Inst.* **207**, p. 369, 1929].

J. M. DallaValle, USA

3928. Kivisild, H., Wind effect on shallow bodies of water with special reference to Lake Okeechobee (Thesis for the doctor's degree), *Trans. roy. Inst. Technol. Stockholm* no. 83, 144 pp., 1954.

When a strong wind blows over a shallow lake, river, or bay, not only waves arise, but the surface water drives in the direction of the wind and accumulates at the leeward shore. At the opposite side the water sinks and so the water surface becomes in-

clined. The inclination is greater on shallow than on deep lakes: the water flows more easily where the water is deep. This phenomenon is well known, but the mathematical theory has until now been mainly occupied with the streaming of the water in the vertical plane through the wind direction. Author has developed a more complete theory, which also includes the streaming perpendicularly to that vertical plane, and has simplified this theory through approximations to make it fit for use. This is necessary for the study of the great but shallow Lake Okeechobee in Florida, which flows over its banks during hurricanes. To solve his differential equations, author divides the sea surface into a net of equilateral triangles and uses a numerical method.

A comparison of calculated and measured water levels in Lake Okeechobee during five hurricanes indicated that the suggested calculation methods are applicable, although full agreement in all cases was not reached. Once a design storm has been determined, the developed methods will permit an estimate of maximum wind effect and will supply design data for various civil-engineering works.   O. H. Faxén, Sweden

3929. Jaeger, C., Present trends in surge tank design, *Proc. Instn. mech. Engrs.*, **168**, 2, 91–124, 1954.

This paper is a very interesting account of the present state of knowledge of the technique of surge tanks. The author, who is an eminent specialist in this field, studies particularly the problem of stability in surge tanks provided with a constant or variable section and having or not having a construction at their base, without neglecting surge-tank differential or connection to a local narrowing of the feed canal (according to the device named "montage Venturi"). The case where several surge tanks concern the same power station is also reviewed. Noting the recent rapid progress of research in this field, it would be fitting to add some new data to the account of Mr. Jaeger, although this was a perfect restatement of the subject at the very time of its publication in November 1953.   L. Escande, France

3930. Zicman, B., New methods for surge-tank calculations (in French), *Houille blanche* **8**, 5, 580–598, Oct. 1953.

Author is mainly concerned with the surges in restricted orifice surge tanks. He shows that the basic equations may be integrated in two cases: (a) sudden total closing of the turbine gates, and (b) the case where the total pressure at the bottom of the tank remains constant and the discharge through the turbines is also constant. Formulas for the maximum surges are given (with numerical examples). A suggestion is made concerning the linearization of the general equations for integration in other cases. Graphical integration is then considered, including the case of closing of small discharges. A new formula is given for the stability of restricted orifice tanks. Finally, the problem of model tests on surge tanks is considered.   C. Jaeger, England

3931. Levin, L., The determination of head losses in surge-tank restricted orifices (in French), *Houille blanche* **8**, 5, 599–606, Oct. 1953.

The methods used for the calculation of surges in throttled surge tanks give reliable results, provided the losses produced on the restricted orifices are known. Author considers several cases of throttles according to their length and design. In some cases the total loss is equal to the sum of the losses produced by all the different elements of the throttle (examples are given); in others, one element is prevailing; and in still other cases, no estimate at all can be made, and model tests are indispensable. For "total closing of the turbine gates," the loss curve is a parabola. For "opening of the gates" the loss curve differs from the parabola.   C. Jaeger, England

3932. Escande, L., and Nougaro, J., Theoretical and experimental investigations of full-flowing tailrace tunnel behavior in the absence of a surge tank (in French), *Houille blanche* 8, 5, 607–639, Oct. 1953.

Low-head underground power stations are usually provided with a surge tank. The so-called "condition of Thoma" for stable oscillations determines the dimensions of this surge tank, which, in some cases, is a structure of considerable dimensions. The alternative solution is a hydraulic system entirely under pressure, with no surge tank at all. The main point to be investigated is the pressure drop (water hammer) created in the full-flowing tailrace tunnel when the turbines are closed instantaneously. The author calculates the pressure drop, the volume of the vacuum created or, alternatively, the volume of air sucked in the pocket and the water discharged when the vacuum or air pocket recloses. Two methods are used: one by direct analytical calculation, the second with the so-called Bergeron pressure-discharge diagrams. Results are compared for three cases: the tailrace without any aeration device, with an air intake valve, with an aeration shaft. The calculation shows that in the first case there is a risk of considerable excess pressures following the pressure drop below cavitation limit. The effect of head losses and of delayed closing of the turbine gates are examined. The pressure drop will decrease substantially with delayed closing of the gates. The theoretical results have been checked on scale models.

C. Jaeger, England

3933. Sokolovskii, D. L., River runoff; methods of investigations and computations [Rechnoĭ stok], Leningrad, Gidrometeor. Izdat., 1952, 491 pp. $2.

This is a recent Russian treatise on applied hydrology and methods used by hydraulic engineers. The introduction of this valuable book gives a historical sketch of the development of this science in Russia, emphasizing the controversy on the influence of forests, lakes, and swamps. Most significant topics are as follows: General water-balance equation for short and long periods, illustrated on several Russian basins, a balance for entire Russia and the globe. Methods of determination of the annual runoff, its variability, frequency curves and their stability. Distribution of runoff during a year, seasonal runoff, winter flow; types of rivers. Probability of daily discharge. Minimum flow in summer and winter. Floods, their source and magnitude, progress and forecast, probability of occurrence. Silt runoff, its computation; silting of reservoirs, bed load, dissolved matter. Artificial change of the runoff: afforestation, soil conservation, flood control, storage reservoirs.

Only four German contributions, one Swiss article, and one American book ("The elements of hydrology" by A. Mayer) are mentioned among 316 titles in the large bibliographical index. Probability method, extensively adapted in the book, was originated by Americans A. Hazen and H. Foster, yet their names were not honored either in text or in bibliographical notes, although their table is entirely copied. Surprisingly enough, this excellent method, thoughtlessly discarded by American hydrologists, was skillfully improved and developed in Russia with very good success. Reviewer agrees with the author, who exalts the merits of Russian hydrologists, such as N. E. Dolgov and D. I. Kocherin; it is regrettable, however, that author did not remember the names of two most important leaders in Russian hydrology, namely, V. G. Glushkov and E. V. Oppokov.

S. Kolupaila, USA

3934. Vasilishin, T. M., Modeling of vortex development (in Russian), *Gidrotekh. Stroit.* 22, 8, 34–37, Aug. 1953.

A free vortex was produced in a container of spiral form with an orifice in bottom. Experiments show that discharge coefficient decreases when the size of model becomes larger. Variation of this coefficient is represented against a dimensionless number $\pi = d^2 g / v v$, which actually means the Reynolds number divided by the Froude number. Two different logarithmic lines were obtained, intersecting at II = 500. Experiments were performed on very small models; for broader conclusions they should be extended to the larger scale.

S. Kolupaila, USA

Incompressible Flow: Laminar; Viscous

(See also Revs. 3782, 3920, 3934, 3975, 3995, 4030, 4035, 4096, 4101)

3935. Eck, B., Technical fluid dynamics [Technische Strömungslehre], 4th rev. ed., Berlin, Springer-Verlag, 1954, x + 422 pp., 407 figs. DM 29.40.

This book fulfills admirably the author's purpose of providing engineers with a concise text and reference book on applied fluid dynamics. After a thorough discussion of the fundamentals of fluid flow, an amazingly wide range of practical topics is considered under the general headings of friction forces, flow separation, cavitation, compressible flow, and hydrodynamic measuring techniques. Over 400 line drawings and photographs supplement the discussion.

A footnote (p. 135) in connection with pipe corrosion seems particularly noteworthy: Colebrook, C. F., and White, C. M., "The reduction of carrying capacity of pipes with ages," *J. Instn. civ. Engrs. London,* no. 1, 99–118, 1937/1938.

A. W. Gessner, USA

3936. Truesdell, C., The kinematics of vorticity, Bloomington, Indiana, University Press, 1954, xvii + 232 pp. $6.

This compact book, which obviously entailed a great deal of labor, scholarship, and loving care in its making, is a mathematical essay in the classical tradition on the invariants associated with vorticity fields. The author is motivated by the special vectorial nature of vorticity in space of three dimensions and by the realization that its kinematic properties are essentially congruent with the foundations of fluid dynamics. The book is valuable (a) as a unified collection with many derivations of classical formal relations of theoretical hydrodynamics, (b) for its rich historical annotations, credit lines, and interpretations, and (c) for its display of recent work in this still very much alive though classical field, including many of the author's own recent contributions.

The reader must bring to the book a modicum of background in vector and tensor analysis and a genuine interest in the mathematical invariants of hydrodynamics. The casting of some familiar results into what may be unfamiliar forms is at once provocative and instructive. As might be expected, for the more recent work particularly, interpretations of results are not always satisfying in view of the abstract quality of many of the general statements. Nevertheless, the author's interpretations are interesting and stimulating. He intentionally excludes wave motion and theory of characteristics or discontinuous motions from the domain of his treatment, and the reviewer believes that additional illumination on many of the results would stem from these realms. Historical notes appear copiously and lead the reader to look forward to a forthcoming history of hydrodynamics by the author, entitled "Rational fluid mechanics 1687–1765." It may, however, come as a shock to some, and at least seem heretical to others, that "Stokes' theorem" on line integrals should properly be "Kelvin's transformation."

The book (which is set in type in the best mathematical form, though paper-covered) contains the following chapter headings:

1 Geometrical preliminaries; 2 Kinematical preliminaries; 3 Vorticity; 4 The vorticity field; 5 Vorticity measures; 6 Vorticity averages; 7 Bernoullian theorems; 8 Convection and diffusion of vorticity; 9 Circulation-preserving motions.

No quite comparable book gathering together the same material exists and, in the opinion of the reviewer, it represents a contribution of unusual interest to the literature of theoretical hydrodynamics.　　　　　　　　　　　　I. E. Garrick, USA

3937. Neumark, S., Velocity distribution on thin bodies of revolution at zero incidence in incompressible flow, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2814, 42 pp., July 1950, published 1954.

The proposed approximate method for calculating the velocity distribution on slender bodies of revolution in subsonic axial flow is especially noteworthy for its simplicity and ease of calculation. Utilizing the equation for the meridian line, either in the form of a polynomial or a square root of one, the velocity distribution on a body may be simply calculated. The velocity distribution about many body shapes may be critically examined to determine the most advantageous body shapes from an aerodynamic standpoint.

The proposed method may prove valuable to designers and aerodynamicists who seek a compromise between the constructional and technological requirements and the aerodynamically desirable shapes.　　　　　　　　　　　　J. Persh, USA

3938. Wick, B. H., Study of the subsonic forces and moments on an inclined plate of infinite span, *NACA TN* 3221, 25 pp., June 1954.

After critical comparison between experimental results and either the thin-airfoil theory, satisfactory up to 8° angle of attack, or the Rayleigh-Kirchhoff theory, a simple empirical modification of this theory is given, allowing to provide lift, normal force, and drag in good approximation up to 30° angle of attack, when flow is completely separated from the upper surface. Experimental values of flat-plate and NACA profiles of the upper-surface pressure coefficient are given in a single curve and directly substituted in place of the theoretical. Pitching moment coefficient and, as author believes, effect of compressibility were not sufficiently defined, however, for prediction to be evaluated.

F. Keune, Sweden

3939. Kuo, Y. H., On the flow of an incompressible viscous fluid past a flat plate at moderate Reynolds numbers, *J. Math. Phys.* 32, 2/3, 83–101, July-Oct. 1953.

Starting from the Blasius solution, the next approximation for the two-dimensional viscous flow along a flat plate of finite chord and zero incidence is developed.

In the drag, an extra term of order Re^{-1} is found, in fair accordance with experiment for $Re > 20$. Flow singularity at the leading edge can be avoided by using the Lighthill method of coordinate perturbation.　　　　　　　　　L. J. F. Broer, Holland

3940. Scholz, N., Calculation of pressure distribution on a straight airfoil in a lattice (in German), *Abh. Braunschweig. Wiss. Gesellsch.* 5, 152–163, 1953.

The conformal representation transforming a lattice composed of straight airfoils into a circle is considered, following von Kármán and Burgers, and the corresponding mapping function as well as the stream function are established. In the general case of a staggered lattice, the stream function is built up of contributions, each representing a simple flow. The velocity distribution along a straight airfoil in the lattice is deduced from the complex velocity by means of the expressions for the mapping function and

the stream function. The velocity distribution and the pressure distribution are then calculated for the chord-gap ratio 0.5 and angles of stagger 0°, 30°, 60°. From the equation which establishes the relation between the parameter κ of the conformal representation and the chord-gap ratio, the values of κ are calculated for different values of the angle of stagger. Paper contains also a table with values of the factor k_0, denoting the ratio of the circulation for the plate in the lattice to the circulation for the single plate.　　　　　　　J. Beránek, Czechoslovakia

3941. Elrod, H. G., Jr., Computation charts and theory for rectangular and circular jets, *Heating, Piping & Air Cond.* 26, 3, 149–155, Mar. 1954.

Charts are presented for computation of velocity distributions and entrainment ratios in free turbulent jets of a constant density fluid entering a stationary field of the same fluid from circular and rectangular sources. Results are obtained from Reichardt's diffusion equation, the basis of which is the similarity between momentum diffusion with distance from orifice and heat diffusion from a line source with the square root of time. Results are compared with empirical data of several experimenters and found to agree well enough for engineering purposes. Value of paper is primarily in its presentation of a convenient analytical and graphical approximation of empirical and theoretical knowledge.

E. W. Price, USA

3942. Gurevich, M. I., and Khaskind, M. D., (Potential) **flow around a slightly vibrating contour** (in Russian), *Prikl. Mat. Mekh.* 17, 3, 599–603, Sept./Oct. 1953.

Two-dimensional (flat) potential flow of an ideal incompressible, light fluid is assumed. Mathematical form, either of potential or of conformal transformation on a half plane, for a rigid contour coinciding with the vibrating contour at a certain moment, is assumed known, i.e., arbitrarily given. To avoid mathematical difficulties, only first approximation in stating boundary conditions is involved. Moreover, the flow is considered symmetrical to the axis coinciding with flow direction, and the vibrations harmonical. Finally, pressure on the free boundary is assumed constant and equal to that in the stream at infinity. Computation is based on previous papers by Gurevich, Siedov (in Russian), and Brodetsky [*Proc. roy. Soc.*, 1923]. Solution involves functions related to error integral (in particular case of vibration of a flat strip it is shown to be easily integrable). It is in a form of two terms: the first depends on the contour shape and causes no waves in the flow; the other causes waves, these being independent of contour shape. The latter influences only amplitude and phase of waves.　　　B. Szczeniowski, Canada

3943. Chertock, G., The flexural response of a submerged solid to a pulsating gas bubble, *J. appl. Phys.* 24, 2, 192–197, Feb. 1953.

A bubble in a liquid pulsates and generates a changing pressure field. This reacts with a submerged flexible solid and induces elastic motions. Equations are derived which show how each mode is excited by the bubble pulsation. The generalized force for each mode is proportional to the volume acceleration of the bubble. The initial analysis presupposes incompressive flow, but it is shown that the results remain applicable if the duration of any compressive phase is small compared to the pulsation period of the bubble and the vibration period of the solid. Reviewer feels that, as the problem solved is of interest particularly in cavitation studies, the immediate usefulness of the solution is severely limited by the restriction of incompressibility. In cavitation, the most interesting period of bubble growth is when the velocities are so high that the compressibility effects are important.　　　　　　　　　　　　P. Griffith, USA

3944. Borodin, V. A., and Ditiakin, Yu F., Stability of plane flows of viscous fluid between two surfaces (in Russian), *Prikl. Mat. Mekh.* 17, 3, 569–578, Sept./Oct. 1953.

Lin's conclusion on the same problem which shows the existence of unstable laminar flow for large Reynolds number was not confirmed by experiments. The discrepancy between the theory and the experiment is considered as due to the imperfectness of the method of mathematical analysis. In 1940, G. I. Petrof showed that the flow through a tube or between two plates is stable, using Galerkin's method. However, Tollmien gave that the flow is unstable when the velocity distribution has a turning point.

Authors show the existence of unstable laminar flow between two plates with an unsymmetrical velocity distribution. The critical Reynolds number is obtained to be 340. The reviewer believes that the turning point in Tollmien's theory is the point on the boundary of sublayer of turbulent boundary layer, and the laminar boundary layer is always stable unless the flow transits to turbulent. M. Kataoka, Japan

Compressible Flow, Gas Dynamics

(See also Revs. 3782, 3935, 3936, 3964, 3967, 3975, 3981, 3986, 4006, 4026)

3945. Morawetz, Cathleen S., Asymptotic solutions of the stability equations of a compressible fluid, *J. Math. Phys.* 33, 1, 1–26, Apr. 1954.

Former investigations of the stability of the laminar boundary layer in a compressible fluid carried out by L. Lees and C. C. Lin [*NACA TN* no. 1115] made use of formal asymptotic series, being formal solutions of a sixth-order system of differential equations; here a large parameter (Reynolds number) is involved. Author proves that these formal series actually represent solutions of the given system. Moreover, he establishes certain properties of the solutions and investigates the behavior of the solutions in the neighborhood of singular points. Conclusions of practical interest are: (1) Author finds that Lees and Lin have used the proper branch of the multiple-valued asymptotic solutions. (2) Results concerning the existence or absence of inner viscous regions. R. Sauer, Germany

3946. Kline, S. J., and Shapiro, A. H., One-dimensional steady gas dynamics for an arbitrary fluid, "Mémoires sur la mécanique des fluides," *Publ. sci. tech. Min. Air, Paris,* 171–202, 1954.

Subject of the paper is the discussion of the following steady one-dimensional motions for single-phase substances (i.e., substances in which entropy and specific volume determine all other thermodynamic properties): (1) isentropic flow, (2) frictionless constant-area flow with heat transfer (Rayleigh line), (3) normal shock waves, (4) adiabatic constant-area flow with friction (Fanno line). Fundamental equations are established and graphical interpretations are given in detail. The signs of the derivatives $(\partial^2 p/\partial v^2)$, and $(\partial p/\partial s)$, determine the qualitative behavior of the motions. If, and only if, both derivatives are positive, the changes in the flow are qualitatively like the changes in a perfect gas.
R. Sauer, Germany

3947. Letko, W., and Danforth, E. C. B., III, Theoretical investigation at subsonic speeds of the flow ahead of a slender inclined parabolic-arc body of revolution and correlation with experimental data obtained at low speeds, *NACA TN* 3205, 56 pp., July 1954.

Approximate expressions for the incremental pressure coefficient and flow inclination ahead of slender parabolic-arc bodies of revolution at zero or small angles of attack or sideslip are derived with the help of the linearized subsonic theory. Numerical results are compared with experimental data. For a Mach number of 0.21, a body of fineness ratio 6, angles of attack less than 20, the comparison shows that the developed approximate theory can be used for predicting the optimum location of static pressure and angle-measuring pickups. The interference of the supporting boom on the angle-of-attack measurement is also analyzed and it is shown that effect may be large enough for some configurations to influence the best location of an angle-measuring pickup. H. H. Hilton, USA

3948. Serrin, J. B., Comparison theorems for subsonic flows, *J. Math. Phys.* 33, 1, 27–45, Apr. 1954.

The maximum principle for elliptic equations yields comparison theorems for two-dimensional or axially symmetric incompressible flows. They are modified and extended in this paper to apply to subsonic compressible flows. With the aid of these theorems it is possible in some cases to estimate velocity distributions by comparing with known solutions or to estimate the effect of a perturbation of the boundary of a known flow. It is also possible to fix, approximately, the position where sonic velocity is reached on an airfoil at critical speed. Note: the third column of Table 1 should read $\alpha'/(\pi - \alpha')$. L. H. Schindel, USA

3949. Mollø-Christensen, E., Characteristic solution for axially symmetric transonic flow, *J. aero Sci.* 21, 7, p. 501, July 1954.

In slightly perturbed plane and axially symmetric transonic flow, it is shown that the velocity potential in the case of simple waves is a product of two functions of single variables.
Y. H. Kuo, USA

3950. Imai, I., Extension of von Kármán's transonic similarity rule, *J. phys. Soc. Japan* 9, 1, 103–108, Jan.-Feb. 1954.

An attempt is made to improve von Karman's transonic similarity rule by including additional second-power terms in thickness. The approximate equation of motion, including all second-power terms, is reduced to a form convenient for solution by iteration. To obtain similitude, it is found necessary to disregard, in the condition of tangent flow at the airfoil, a second-power term that is less significant near $M = 1$ than certain of those retained in the equation of motion. This leads to a rule that can be obtained from von Kármán's by replacing $(\gamma + 1)$ wherever it appears by $(\gamma + 1)M^4 + 4M^2(1 - M^2)$. Liepmann and Bryson's drag measurements on wedges [AMR 4, Rev. 3298] are replotted in this way, but the correlation is scarcely improved. The author proposes seeking improvement by retaining also the second-power term in the tangency condition.

Reviewer notes that von Kármán's rule is known to apply through the whole range of Mach numbers from subsonic to supersonic, though the original derivation appears to be limited to transonic. Since in the transonic range certain terms of third and higher power in thickness are of the same order as those added here, improvement of correlation cannot necessarily be anticipated. However, Hayes, in supposedly reproducing the present results as announced before publication [British *Aero. Res. Counc.* 15, 722, 1953], has accounted for all second-power terms—the resulting rule is obtained from von Kármán's by replacing $(\gamma + 1)$ by $(\gamma + 1)M^4 + 4(1 - M^2)$—and then, as author conjectures, the correlation is considerably improved. Still, it falls somewhat short of the remarkable results obtained simply by replacing $(\gamma + 1)$ in von Kármán's rule by $M^2(\gamma + 1)$, as discussed by Spreiter [*J. aero. Sci.* 21, 1, 70–72, Jan. 1954].
M. D. Van Dyke, USA

3951. Van Dyke, M. D., A study of hypersonic small-disturbance theory, *NACA TN* 3173, 51 pp., May 1954.

Systematic study has been made of approximate inviscid theory of thin bodies moving at such higher supersonic speeds that nonlinearity is an essential feature of the flow. First-order equations were derived for three-dimensional motions. Hypersonic theory was interpreted such that it and associated similarity rules apply at all supersonic speeds above the transonic zone. Small disturbance solutions were given for flow past a wedge and cone and for the initial gradients at the tip of plane and axially symmetric ogives. H. R. Ivey, USA

3952. Van Dyke, M. D., Applications of hypersonic small-disturbance theory, *J. aero. Sci.* 21, 3, 179–186, Mar. 1954.

A simple theory of inviscid hypersonic flow is studied which provides a first approximation as thickness parameter $\tau \to 0$ and Mach number $M \to \infty$ in such a manner that $1/(M\tau) = 0(1)$. Introducing in the full equations of motion and in the shock equations suitable variables that are of order unity, and discarding terms that contain τ^2 explicitly, a system of reduced small-disturbance equations is obtained which retains the essential nonlinearity of the problem. By suitably reinterpreting the solutions of these hypersonic equations, they can be shown to remain valid even for small values of $M\tau$ (which is the domain of linearized supersonic theory) if $M\tau$ is replaced by $\beta\tau$ ($\beta = (M^2 - 1)^{1/2}$). Thus, for example, with this substitution the hypersonic similarity rule for C_p/τ^2 covers the entire range of supersonic flows (C_p pressure coefficient).

The accuracy of the theory is greater than in the transonic or supersonic small-disturbance theory, but can be further increased by interpreting its results in conformity with Newtonian impact theory. Also, with the aid of this idea its range of applicability can be much extended at high supersonic speeds if extrapolation to thicker shapes is made by assuming a sine-squared variation. This is strikingly shown at $M = \infty$ for circular cones of semivertex angles as extreme as 50°.

To show the utility of hypersonic small-disturbance theory, three problems connected with pointed bodies of revolution are treated: The determination of (1) the pressure coefficient for circular cones, showing the very good degree of approximation obtainable; (2) the initial flow gradients at the nose of ogives, showing that a logarithmic singularity originally claimed to have been found by Shen and Lin [*NACA TN* 2505, 1951] is, in fact, illusory; and (3) further terms in a power-series expansion for surface pressure on an ogive described itself by a power series, showing, by the use of Lighthill's technique to render approximate solutions uniformly valid, that three terms in the power series describe the pressure distribution with good accuracy over little less than half the length of a circular-arc ogive.

H. Behrbohm, Sweden

3953. Pack, D. C., and Pai, S.-I., Similarity laws for supersonic flows, *Quart. appl. Math.* 11, 4, 377–384, Jan. 1954.

Similarity laws for the Mach number range $1 < M < \infty$ are found for the steady three-dimensional irrotational supersonic flow past a wing. First it is shown that, for the linearized theory, the parameters $K_1 = (M^2 - 1)^{1/2}/\tau^n$ and $K_2 = A(M^2 - 1)^{1/2}$ (where τ is the nondimensional thickness ratio, A is the aspect ratio and n is arbitrary) must be constant for similarity laws to hold. Then by considering the most important nonlinear terms neglected in the linearized theory, the authors obtain functional relations $n = f_1(M, \tau)$ for $0 < n < 1/3$, and $n = f_2(M, \tau)$ for $-1 < n < 0$ appropriate to transonic-supersonic and supersonic-hypersonic flow, respectively. The equations for K_1 and K_2, together with the relations for n, are termed a "generalized similarity

law," which, since $f_1 \to 1/3$ as $M \to 1$ and $f_2 \to -1$ as $M \to \infty$, yields as special cases the usual transonic and hypersonic laws. As f_1 and f_2 are deduced from different nonlinear terms, the generalized similarity law will be unreliable in the intermediate case $n = 0$.

Reviewer considers the paper a valuable contribution to the subject. L. C. Woods, Australia

3954. Laporte, O., and Turner, E. B., On the interaction of two plane shocks facing in the same direction, *J. appl. Phys.* 25, 5, p. 678, May 1954.

A preliminary report of an experimental technique which produces two equally facing shocks separated by a constant state in a shock tube. After the two shocks collided, a surface of density discontinuity was observed. Y. H. Kuo, USA

3955. Chester, W., The shock strength in the regular reflection of weak shock waves, *J. aero. Sci.* 21, 5, 347–349, May 1954.

The problem of a weak plane shock impinging upon a thick infinite wedge whose leading edge is yawed is treated, using the conical field method. Especially, the results of Lighthill [AMR 6, Rev. 2716] are used to discuss the nature of the reflected shock. H. Yoshihara, USA

3956. Chester, W., The diffraction and reflection of shock waves, *Quart. J. Mech. appl. Math.* 7, part 1, 57–82, Mar. 1954.

The procedure of Lighthill [AMR 6, Rev. 2716] is extended to include the case in which the plane shock impinges upon an infinite wedge which is yawed and at a small incidence. The pressure distribution on the wedge is computed for several angles of yaw and for several different values of the shock strength.

H. Yoshihara, USA

3957. Hollyer, R. N., and Laporte, O., Parameters characterizing the strength of a shockwave, *Amer. J. Phys.* 21, 8, 610–613, Nov. 1953.

A parameter is proposed which consists only of quantities on one side of the shock wave, and either side may be the one on which they are taken. For a steady one-dimensional flow density, speed and pressure are constant except in passing through the shock, if the fluid is nonviscous and nonheat-conducting. These three quantities determine three other quantities which do not change even in passing through the shock; the former triplet is a two-valued function of the latter. A function of either triplet of values and of the quotient of the specific heats at constant pressure and at constant volume is the proposed parameter. The discussion is carried through for normal shocks; the generalization is trivial. E. W. Beth, USA

3958. Krzywoblocki, M. Z., Remarks on "Shock-wave effects on the laminar skin friction of an insulated flat plate at hypersonic speeds," *J. aero. Sci.* 20, 11, 799–800, Nov. 1953.

3959. Kestin, K., and Zaremba, S. K., Adiabatic one-dimensional flow of a perfect gas through a rotating tube of uniform cross section, *Aero. Quart.* 4, part 4, 373–399, Feb. 1954.

Authors treat the air flow through the rotating hollow blade of a pressure jet helicopter with pressure gradient and acceleration, leading to an extension of the classical equations of motion and energy. The flow is then turned 90° through a nozzle to provide the thrust for the turning moment. The resulting nonlinear ordinary differential equation, not integrable, is analyzed for singular points and for the asymptotic behavior of the integral curves. Depending on entrance velocity and angular speed of the

blade, the flow may be subsonic, sonic, or supersonic; shock wave formation is investigated. Numerical step-by-step integration or isoclines which become conics may be used. The initial conditions are determined for two problems: The design problem, where the throat area of the driving nozzle is to be found for a given inflow velocity, mass flow, and angular velocity; the performance problem, where the throat area is given and the relation between inflow velocity and mass flow is to be found. Authors also give an approximate solution in closed form for small entrance velocities and determine the pressure distribution along the duct.   G. R. Graetzer, USA

3960. Cole, Isabella J., and Margolis, K., Lift and pitching moment at supersonic speeds due to constant vertical acceleration for thin sweptback tapered wings with streamwise tips. Supersonic leading and trailing edges, *NACA TN* 3196, 67 pp., July 1954.

Stability derivatives are evaluated on the basis of a solution to the linearized time-dependent wave equation. Results are given in the form of design charts, from which fairly rapid estimations of the derivatives can be made for given values of Mach number, aspect ratio, leading-edge sweepback, and taper ratio. Some chordwise pressure distributions, spanwise pressure distributions, span-load distributions, and variations of the stability derivatives with several parameters are also included. Some results of the present investigation are combined with previous calculations available for the steady-pitching derivative to indicate the variations of the total pitching-moment derivative with wing geometry and Mach number. These calculations are applicable to slowly (first-order frequency) oscillating wings.

From authors' summary by T. Gullstrand, Sweden

3961. Woods, L. C., and Phil, D., Two-dimensional aerofoil design in compressible flow, *Aero. Res. Counc. Lond. Rep. Mem.* 2731, 19 pp., Nov. 1949, published 1953.

A relaxation method is presented for the design of an airfoil to give a specified velocity distribution at a given free-stream Mach number. The method is developed for a symmetrical airfoil at zero incidence, but the modifications necessary for the more general case are indicated. An example is given from which some idea of the accuracy of the method can be gained.

From authors' summary by J. R. Spreiter, USA

3962. Jack, J. R., and Moskowitz, B., Experimental investigation of temperature recovery factors on a 10° cone at angle of attack at a Mach number of 3.12, *NACA TN* 3256, 15 pp., July 1954.

Temperature recovery factors on a thin-walled, metal, 10-degrees included angle cone were obtained at a Mach number of 3.12 over a range of angles of attack from 0 degrees to 10 degrees and for Reynolds numbers per foot from 1.5 million to 8 million. Over the Reynolds number range investigated, an increase in angle of attack increased the equilibrium surface temperatures in the laminar and turbulent boundary-layer regions. The equilibrium surface temperatures in regions of probable cross-flow separation were in the same range as those obtained for fully turbulent flow.

For the windward surface of the model, local recovery factors in the fully laminar and turbulent regions were not significantly affected by changes in angle of attack. At all angles of attack, increasing the free-stream Reynolds number moved the transition region upstream. For a given angle of attack, the transition region on the leeward surface is substantially upstream of that on the windward surface.

From authors' summary by R. C. Roberts, USA

3963. Chu, S. T., and Tifford, A. N., The compressible laminar boundary layer on a rotating body of revolution, *J. aero. Sci.* 21, 5, 345–346, May 1954.

The Prandtl number is assumed to be unity and the enthalpy is assumed to be a function of H only, where H is a specified function of the velocity components and the rate of rotation and involves an arbitrary constant k. It is then shown that a particular solution of the energy equation takes a form similar to that derived by Crocco for two-dimensional flow with zero heat transfer (i.e., constant total energy), but in this case, by suitable choice of k, a range of temperature boundary conditions can be satisfied. It is then demonstrated that by means of a transformation reminiscent of that due to Mangler, the boundary-layer equations can be transformed to equations which, it is claimed, relate to an associated incompressible-flow problem. The precise physical nature of this latter problem and the method of solving the transformed equations are not discussed.

A. D. Young, England

Turbulence, Boundary Layer, etc.

3964. Burgers, J. M., On the coalescence of wave like solutions of a simple non-linear partial differential equation. I, II, III, *Proc. k. Ned. Akad. Wet (B)* 57, 1, 46–72, Jan./Feb. 1954.

The wavelike solutions of the differential equation

$$v_t + v v_y = \nu\, v_{yy} \qquad (\nu \ll 1)$$

with successive positive impulses introduced at $y = 0$ and $t = t_n$ ($n = 1, 2,$) are considered. These impulses give rise to waves with steep fronts (shock waves) propagating in positive y-direction with speed dependent on the strength of impulse. The mechanism of catching-up and the merging of successive waves are studied. Expressions are then deduced for the probability of merging of the wave system due to a random distribution of impulses. In this way the remaining waves at great distance from origin are obtained.

It is pointed out that, as a consequence of the nonlinear character of the differential equation, this randomness in boundary condition (e.g., standard deviation of amplitudes) is prevented from being smoothed out, and constitutes an essential parameter remaining visible in the final result.

Besides being of mathematical interest as it presents a typical treatment of the random boundary-value problem, the study is a valuable contribution to the understanding of the nature of compressible turbulence at high Mach number (in particular, the turbulence of interstellar gas). The idea of generation of this compressible turbulence by the randomness in boundary condition is much in contrast to the prevailing view of the development of incompressible turbulence through instability, i.e., effect of Reynolds number.   H. S. Tan, USA

3965. Ogura, Y., The relation between the space- and time-correlation functions in a turbulent flow, *J. meteor. Soc. of Japan* (2) 31, 11/12, 355–369, Dec. 1953.

Expressing one component of turbulent velocity fluctuations by a Fourier integral, author shows that $1 - R(t) \sim t^m$; where t is time, $R(t)$ the Eulerian time-correlation function, and $2/3 \leqslant m \leqslant 1$, m approaching $2/3$ when the mean velocity U is large and approaching 1 when U is small. Thus when U is large, $R(t)$ can be obtained from the space-correlation function $R(r)$ by substituting tU for r in $1 - R(r) \sim r^{2/3}$.   J. E. Miller, USA

3966. Favre, A., Gaviglio, J., and Dumas, R., **Some auto-correlation functions and energy spectra of turbulence, downstream of a screen** (in French), *C. R. Acad. Sci. Paris* **238**, 15, 1561–1563, Apr. 1954.

3967. Monaghan, R. J., **A review and assessment of various formulae for turbulent skin friction in compressible flow,** *Aero. Res. Counc. Lond. curr. Pap.* 142, 40 pp., 10 figs., Oct. 1953.

Author surveys various formulas for turbulent skin friction on a flat plate in compressible flow, with and without heat transfer. He also examines the assumptions made in their development, checking them against available experimental evidence. Conclusion is reached that the shearing stress assumption $\tau_0 = \rho k^2 U''^4 / U''^2$ (von Kármán's form) gives values of turbulent skin friction in best agreement with experimental results in the range $1.6 < M < 2.8$ under zero heat-transfer conditions. However, the author expresses preference for the simpler approach of the assumption of constancy of velocity profile used by Cope for zero heat transfer and by Monaghan and Johnson with heat transfer. Experimental data up to a free-stream Mach number 4.5 are given to corroborate the above conclusion. It is suggested that these formulas may be applied to heat-transfer conditions if interpreted in terms of the ratio of wall-to-stream temperature ratio. An interpolation formula given by Rubesin is also shown to give good results. Further experimental checks of heat-transfer cases are highly recommended.   C. C. Lin, USA

3968. Dryden, H. L., **Effects of roughness and suction on transition from laminar to turbulent flow,** "Mémoires sur la mécanique des fluides," *Publ. sci. tech. Min. Air, Paris,* 49–60, 1954.

This paper, in connection with author's earlier one [AMR **6**, Rev. 561], represents a very important critical evaluation and correlation of available data and thus paves the way for better planning of future research programs. The increased stability of a laminar boundary layer due to suction, as inferred from the Tollmien-Schlichting theory, is not fully realized in experiments; surface roughness seems to be the adverse element which reduces the gains from suction. On a flat plate, with only one two-dimensional roughness element (wire), the transition position moves upstream from its original position but still remains downstream of the roughness element, reaching it only when the height of the roughness element, or the stream speed, is increased. One important parameter is the ratio of height k of the element to the displacements thickness δ^* of the boundary layer. For the most critical location, this parameter seems to be 0.5 when k is less than 0.00047 in.; at 12 in. from the leading edge, a single roughness element 0.006 in. high completely eliminated the stabilizing effect of suction. For airfoils, only speculation is possible on the combined effects of roughness and suction.

G. R. Graetzer, USA

3969. Pai, S.-I., **On turbulent flow in circular pipe,** *J. Franklin Inst.* **256**, 4, 337–352, Oct. 1953.

Author makes some rather trivial deductions from the equations of turbulent flow in a circular pipe.

K. Stewartson, USA

3970. Truckenbrodt, E., **Calculation of profile drag based on the knowledge of the shape of the profile** (in German), *Ing.-Arch.* **21**, 3, 176–186, 1953.

This is an attempt to combine potential-flow airfoil theory and boundary-layer theory so as to give the profile drag of an airfoil directly in terms of the profile geometry. Approximate results due to Squire and Young [*Aero. Res. Counc. Rep. Mem.* no. 1838, 1938], Pretsch [*Jahrb.* 1938 der deutsch. Luftfahrtforschung, I 61], and the author [AMR **6**, Rev. 1341] are combined, and an approximation to the flat-plate skin-friction formula for a boundary layer partly laminar and partly turbulent is also introduced. The potential velocity distribution is taken from the theory of thin, uncambered profiles and is expressed by a definite integral of the profile slope. This is put into the skin-friction formula and the result is linearized. As a further simplification, the definite integrals remaining in the resulting formula for the profile drag are expressed as summations over the profile ordinates, and the various coefficients needed are tabulated in the paper. Reynolds number, roughness, and transition-point location are parameters to be chosen.

The method is applied here to a Joukowsky profile, an ellipse, and several families of airfoil profiles. Finally, the influence of camber is estimated in a rough way. It is concluded that this increment of profile drag is proportional to the square of the camber and the constant of proportionality is worked out approximately for several types of camber.   W. R. Sears, USA

3971. Preston, J. H., **The determination of turbulent skin friction by means of pitot tubes,** *J. roy. aero. Soc.* **58**, 518, 109–121, Feb. 1954.

A simple method of determining local turbulent skin friction on a smooth surface has been developed which utilizes a round pitot tube resting on the surface. Assuming the existence of a region near the surface in which conditions are functions only of the skin friction, the relevant physical constants of the fluid, and a suitable length, a universal nondimensional relation is obtained for the difference between the total pressure recorded by the tube and the static pressure at the wall, in terms of the skin friction. This relation, on this assumption, is independent of the pressure gradient.

The truth and form of the relation were first established, to a considerable degree of accuracy, in a pipe, using four geometrically similar round pitot tubes—the diameter being taken as a representative length. These four pitot tubes were then used to determine the local skin-friction coefficient at three stations on a wind-tunnel wall, under varying conditions of pressure gradient. At each station, within the limits of experimental accuracy, the deduced skin-friction coefficient was found to be the same for each pitot tube, thus confirming the basic assumption and leaving little doubt as to the correctness of the skin friction so found.

Pitot traverses were then made in the pipe and in the boundary layer on the wind-tunnel wall. The results were plotted in nondimensional forms on the basis already suggested and they fell close together in a region whose outer limit represented the breakdown of the basic assumption; but, close to the wall, the results spread out, due to the unknown displacement of the effective center of a pitot tube near a wall. This again provides further evidence of the existence of a region of local dynamic similarity and of the correction of the skin friction deduced from measurements with round pitot tubes on the wind-tunnel wall. The extent of the region in which the local dynamic similarity may be expected to hold appears to vary from about $1/5$ to $1/20$ of the boundary-layer thickness for conditions remote from, and close to, separation, respectively.

From author's summary by C. E. Carver, Jr., USA

3972. Roop, I., **Experimental investigation of turbulence and transition in fluid flow** (in French), "Mémoires sur la mécanique des fluides," *Publ. sci. tech. Min. Air, Paris,* 271–281, 1954.

A model for the study of turbulence proposed by D. Riabou-

chinsky. In a glass balloon filled with water a vane wheel is driven by a motor the power W of which is measured as it depends on the number of revolutions N_1 of the wheel. The whole apparatus rotates about an axis perpendicular to the axis of the vane wheel with a number of revolution N_2. A graph W vs. N_2 for three values of N_1 shows how the laminar-turbulent transition depends on N_1 and N_2.   K. Wieghardt, Germany

3073. Ross, D., and Robertson, J. M., An empirical method for calculation of the growth of a turbulent boundary layer, *J. aero. Sci.* 21, 5, 355–358, May 1954.

An empirical expression is presented as a correction to the boundary-layer momentum equation to account for flows with transverse pressure gradients. In simplified forms, momentum thickness calculations are fitted to a collection of data on two-dimensional flows and for a conical diffuser. Since more rigorous (and tedious) computations in the presence of strong pressure gradients would not necessarily be productive of more exact answers, the method appears useful where rapid approximations are required, except in the region of separating flow.

    H. M. Spivack, USA

3074. Kaiser, H., Application of Reynolds similarity law to the flow resistance and extension phenomena in turbulent boundary layers (in German), *Meteor. Rdsch.* 6, 7/8, 121–126, July/Aug. 1953.

In the turbulent motion of a fluid, the sum $\mu + \zeta$ has to be substituted to the viscosity μ. A consequence of this substitution in the study of the motion of a sphere in a fluid is that the expression of the Reynolds number Re becomes $\rho du/(\mu + A_0 \rho du)$: ρ is the density of the fluid, d the diameter of the sphere, u the velocity, and A_0 the "Austausch" coefficient. In the case of overwhelming inertia forces, this expression can be reduced to $1/A_0$.

Author presents results of essays on models and on prototypes corresponding to very different values of the Reynolds number ud/ν. Author explains that, notwithstanding this difference, the considered results are in very good agreement because the Reynolds number for the turbulent motion, $Re = 1/A_0$, is almost the same in the two cases.

Author deduces some other conclusions from this theory.

    L. J. Tison, Belgium

Aerodynamics of Flight; Wind Forces

(See also Revs. 3874, 3959, 3970, 3993, 4005)

3975. von Kármán, T., Aerodynamics. Selected topics in the light of their historical development, Ithaca, New York, Cornell University Press, 1954, xii + 203 pp. $4.75.

Theodore von Kármán is one of the (very) few living scientists who can write with authority not only on the mathematical but also on the engineering aspects of the problem of flight. This book on the progress of aerodynamics traces the history, discusses the theory, and leads the reader to the present position of the science in a style so limpid that the neophyte will not be puzzled and the specialist will be delighted. Each chapter is followed by a list of historical and other references which will well repay study. There are 13 portraits of contributors to the science, ranging from Leonardo da Vinci to Lanchester. Of these pioneers four are clean-shaven. The chapters of the book are: Aerodynamic research before the era of flight; The theory of lift; Theories of drag and skin friction; Supersonic aerodynamics; Stability and aeroelasticity; From the propeller to the space rocket.   L. M. Milne-Thomson, England

3976. Tsu, C. N., A note about the effects of product of inertia on lateral stability, *J. aero. Sci.* 21, 7, p. 496, July 1954.

By manipulation of the standard equations of aircraft lateral motion, author presents product of inertia terms in the form of equivalent stability derivatives. Expressed purpose is to facilitate evaluation of product of inertia effects by allowing the use of known methods for inferring the effect of stability derivatives on dynamic stability.   R. M. Spath, USA

3977. Kalkman, C. M., and Buhrman, J., The effect of the compressibility of the air on the dynamic longitudinal stability of an aeroplane in gliding flight, *Nat. LuchtLab. Amsterdam Rap.* 1648, 11 pp., Feb. 1953.

As a continuation of a previous paper by the same authors [AMR **6**, Rev. 3161], the dynamic stability of an airplane gliding in an atmosphere of constant physical properties is investigated.

Compressibility effects in the subcritical region are considered. The classical equations of the disturbed motion are written and the stability quartic is derived.

The short period oscillation and the long period oscillation (phugoid motion) are analyzed according to Bairstow's treatment. The damping and the period of the oscillations are approximately calculated. Compressibility effects are evaluated for various c.g. positions and airfoil configurations.

A numerical example is carried out for a typical high-speed airplane.   A. Miele, USA

3978. Scher, S. H., An analytical investigation of airplane spin-recovery motion by use of rotary-balance aerodynamic data, *NACA TN* 3188, 38 pp., June 1954.

The calculation of spin-recovery motion of an airplane was calculated step by step by using modified-wind-tunnel rotary balance data. Difficulties encountered in using the data in the calculations are discussed. Time history plots are presented.

    T. H. Lin, USA

3979. Martin, J. C., Diederich, Margaret S., and Bobbitt, P. J., A theoretical investigation of the aerodynamics of wing-tail combinations performing time-dependent motions at supersonic speeds, *NACA TN* 3072, 226 pp., May 1954.

A theoretical investigation is presented of the contribution of horizontal tails to the lift and pitching moment due to angle of attack, a constant rate of pitch, and a constant vertical acceleration. Numerical values of the aerodynamic coefficients associated with these motions are presented for a number of two-dimensional wing-tail combinations, a triangular wing-tail combination, and a number of rectangular-wing-triangular-tail combinations.

Methods for calculating the flow fields behind wings with constant vertical acceleration are developed. Calculated results are presented for the upwash behind two-dimensional wings and for certain regions behind triangular and rectangular wings for a constant rate of pitch and for constant vertical accelerations. A method of treating unsteady aerodynamics based on an infinite series of stability derivatives of successively higher order is also presented.   From authors' summary by G. V. R. Rao, USA

3980. Huston, W. B., and Skopinski, T. H., Measurement and analysis of wing and tail buffeting loads on a fighter-type airplane, *NACA TN* 3080, 86 pp., May 1954.

Wing and tail buffeting loads measured in 194 runs with a fighter-type airplane are tabulated with the associated flight conditions. Measurements were made at altitudes of 30,000 to 10,000 ft and at Mach numbers up to 0.8. Preliminary analysis

indicates that the loads vary with the square root of the dynamic pressure and shows the effects of aerodynamic damping, duration of buffeting, maneuver abruptness, penetration beyond the buffet boundary, and reduction of the wing natural frequency in bending through addition of wing-tip weights.

<div align="right">From authors' summary</div>

3981. Pitts, W. C., Nielsen, J. N., and Gionfriddo, M. P., Comparison between theory and experiment for interference pressure field between wing and body at supersonic speeds, *NACA TN* 3128, 64 pp., Apr. 1954.

Pressure measurements in the interference region of a rectangular wing and ogive-cylinder body are compared with the linear wing-body theory of *NACA TN* 2677 [AMR 6, Rev. 565] at Mach numbers 1.48 and 2.0. A brief comparison with theories of Mirokawa and Ferrari is also shown. Pressures on wing and body were measured at angles of attack to 6° and for wing incidence of 1.9° and −5.7°, with the body at zero angle of attack. In general, the theory of *TN* 2677 underestimates the interference pressures by about 10%. The discrepancy is shown to be primarily due to nonlinear effects. The integrated span loading agrees well with linear theory.

In the case of the configuration at angle of attack, the contribution of the body alone has been omitted from the theory. Measurements at high angles of attack and of afterbody pressures have not been included.   L. H. Schindel, USA

3982. Wadlin, K. L., Ramsen, J. A., and Vaughan, V. L., Jr., The hydrodynamic characteristics of modified rectangular flat plates having aspect ratios of 1.00 and 0.25 and operating near a free water surface, *NACA TN* 3079, 64 pp., Mar. 1954.

An investigation has been conducted to determine the hydrodynamic forces and moments acting on modified rectangular flat plates with aspect ratios of 1.00 and 0.25 mounted on a single strut and operating at several depths of submersion. A simple method has been developed by modifications of Falkner's vortex-lattice theory which enables the prediction of the lift characteristics in unseparated flow at large depths. This method shows very good agreement with experimental data from the present tests and with aerodynamic data.

The experimental investigation indicated that decreasing the aspect ratio or depth of submersion caused a decrease in the lift coefficient, drag coefficient, and lift-drag ratio. The center of pressure moved forward with decreasing depth of submersion and aft with decreasing aspect ratio.

Two types of leading-edge separation at high angles were encountered. One type, called "white water" and found only for the aspect-ratio-1.00 surface, caused a slight decrease in the lift and moment coefficients and a slight increase in the drag coefficient. The other type, called the "planing bubble" and found for both surfaces, caused a sharp drop in the lift, drag, and moment characteristics of the order of that to be expected in the transition from the submerged to the planing condition.

<div align="right">From authors' summary by J. V. Becker, USA</div>

3983. Falkner, V. M., and Lehrian, Doris E., Low-speed measurements of the pressure distribution at the surface of a swept-back wing, *Aero. Res. Counc. Lond. Rep. Mem.* 2741, 36 pp., Nov. 1949, published 1953.

Low-speed measurements of the pressure distribution have been made at selected stations on a sweptback wing with and without body. The wing was of 45° sweepback, with a sharp discontinuity at the center section, and of aspect ratio 3 with uniform chord. The airfoil section was chosen to be suitable for work at low Reynolds number, and the wing plan to be of the

maximum utility for comparison of observed and calculated pressure distribution. The work is the first part of a program designed to give results of the greatest assistance to the development of mathematical methods, and the model was of exceptionally clean design to avoid extraneous effects.

The symmetry of the model allowed the work to be duplicated by covering a range of positive and negative incidences and, by averaging, it has been possible to remove zero irregularities due to wind-tunnel flow and to present accurate value of pressure distribution, distribution of local lift coefficient, and center of pressure of normal force for a range of incidence 0 to 16 degrees. Wind-tunnel balance measurements of over-all lift appear to be in reasonable agreement with the pressure plots.

A selection of chordwise pressure distributions is plotted and it is shown that at zero lift for the wing alone there is good agreement with curves calculated at the Royal Aircraft Establishment. A comparison of a potential solution for load grading and local aerodynamic chord with the wind-tunnel measurements at finite lift shows approximately the variation due to the effects of wing thickness and viscosity.   From authors' summary

3984. Legendre, R., Flow near the vertex of a delta wing at moderate angles of incidence (in French), *Rech. aéro.* no. 35, 7–8, Sept.-Oct. 1953.

Author points out how to improve his earlier theory [AMR 6, Rev. 3506] by incorporating a suggestion due to Mac C. Adams. In this modification, account is taken not only of the two vortexes which are produced by separation from leading edge, but also of the vortex sheet which joins them to leading edge. Resulting lift curves are given.   A. Roshko, USA

3985. Klein, H., The calculation of drag from wake surveys, *Douglas Aircr. Co. Rep.* SM-14973, 35 pp., Oct. 1953.

The application of wake survey methods to drag determination is examined. The drag of a closed body or the drag of a protuberance or air inlet or exit on a semi-infinite body may be found by wake measurements through the use of the momentum equation. Measurements of the flow angularity as well as total and static pressures must be made. It is also shown that such measurements taken behind part of a general body or behind a protuberance, inlet, or exit on a nonsemi-infinite body will not satisfactorily determine a drag quantity that has utility. B. M. Jones' formula, which has been found to give correct results for determining airfoil drag, is shown to be consistent with the momentum equation, providing certain approximations are made. It is pointed out that the validity of the Jones formula rests on tests made on airfoils and that it cannot be used with confidence in other cases until experiments establish its validity. Some experiments to verify this extension of Jones' very convenient formula are suggested.   From author's summary by T. Gullstrand, Sweden

3986. Lawrence, H. R., The aerodynamic characteristics of low aspect ratio wing-body combinations in steady subsonic flow, *J. aero. Sci.* 20, 8, 541–548, Aug. 1953.

The linearized flow field about a thin wing of arbitrary twist mounted on an infinite inclined circular cylinder in a uniform incompressible free stream is formulated as the solution of a pair of simultaneous integral equations in two variables. By making use of an extended form of the slender-body approximation, the simultaneous integral equations are shown to be equivalent to a single integral equation valid on the wing surface.

The method employed by the author in references 9 and 15 is used to approximate this two-variable integral equation by a single-variable integral equation for the chordwise lift distribu-

tion. The chordwise lift distribution on the wing-body configuration is shown to be identical with that of a wing with the same exposed planform but altered twist distribution. A procedure for computing the distribution of lifting pressures is presented.

Methods for extending this result to bodies of finite length and to account for the effects of compressibility are discussed.

From author's summary by H. Schlichting, Germany

3987. Pasquarelli, C. G., Calculation of the effective angle of incidence of the horizontal tailplane (in Italian), *Aerotecnica* **33,** 2, 164–165, Apr. 1953.

Wind-tunnel tests show that the effective angle of attack of the horizontal tailplane is influenced by the flow around the wing and around the fuselage. The influence of the wing is proportional to the wing's angle of attack; the influence of the fuselage, however, is almost independent of the angle of attack. It is shown how the fuselage effect can be obtained from wind-tunnel measurements performed with and without tailplane. The described fuselage effect is important for calculation of the tailplane loads in flight conditions with small angle of attack and for cases where the loads produced by stabilizer and elevator, respectively, counteract each other. G. W. Braun, USA

3988. O'Hara, F., Helicopter research, *J. Helicop. Assn.* **7,** 4, 206–221, Apr. 1954.

3989. Cameron, D., British performance reduction methods for modern aircraft, *Aero. Res. Counc. Lond. Rep. Mem.* 2447, 32 pp., Jan. 1948, published 1953.

Aeroelasticity (Flutter, Divergence, etc.)

(See also Rev. 3975)

3990. Williams, D., Recent developments in the structural approach to aeroelastic problems, *J. roy. aero. Soc.* **58,** 522, 403–428, June 1954.

Paper treats calculation of stresses, deflections, vibration modes, and frequencies, with special reference to a delta wing. Structural theory is expressed in terms of difference equations with recommendation that these equations be solved on a digital computer. Matrix of coefficients (stiffnesses) is to be inverted and vibration modes then computed by matrix iteration. Reviewer's experience in the analysis and designing of a number of delta wings indicates that difference equations do provide the best approach to this difficult structural problem.

Author appears to be unaware of the possibilities of analysis on a true dynamic analog computer, or electrical simulator (not a differential analyzer) employing only passive circuit elements. Structural theory, approximately the same as given by author, serves as basis of operation of CalTech analog computer [see AMR **4,** Rev. 3828; **6,** Rev. 1878; **7,** Revs. 2140, 2141]. During past three years a number of delta wings have been designed (not just analyzed) on the CalTech computer.

First part of paper, giving elementary introduction to matrix algebra, has been reproduced in *Engineer, Lond.* **197,** no. 5118, 315–317, Feb. 1954. S. U. Benscoter, USA

3991. Broadbent, E. G., The elementary theory of aeroelasticity. Part IV, *Aircr. Engng.* **26,** 304, 192–200, June 1954.

This concluding article in a series concerned with divergence, aileron reversal, and flutter deals with British practice in avoiding flutter. The subjects covered include the use of stiffness criteria in early design, flutter calculations, ground resonance tests, and aircraft modifications. Of special interest are discussions of such problems as determining which region bounding a flutter curve is stable, and analytically checking measured vibration modes.

A. A. Regier, USA

3992. Hall, A. H., An analysis of the stiffness and optimum weight-stiffness of tubes with inclined ribs, *Nat. Aero. Establ. Canad.* LR-89, 31 pp., 9 figs., Jan. 1954.

The analysis is based on equating the rotations and displacements of rib and wing at the spar joints together with least work principles. The torsional and bending stiffnesses thus derived are modified to fit previously published experimental data. Optimum configurations of rib and wing combinations are determined at constant weight, i.e., by assuming an interchange of material between wing skin and rib. Under these conditions the only variables are the spacing, orientation, and thickness of ribs, and depth, width, and skin thickness of the wing. The actual minimization is made with respect to the skin thickness of wing and rib.

Calculations for a rectangular wing show that the maximum torsional stiffness is achieved when the ribs are inclined at about 42° with the spar. This maximum is 30% greater than the value with the ribs perpendicular to the spar. The bending stiffness increases as the ribs are inclined toward the spar.

Optimum weight-stiffness criteria occur within practical limits for bending but not torsional stiffnesses. Torsional and bending stiffnesses are given in the form of curves for configurations resulting in maximum bending stiffnesses.

Reviewer believes that some modification is necessary in the derived torsional stiffness expression since it assumes that the inclined ribs bend into circular arcs. Also, the author overlooked two important articles on the same subject: AMR 5, Rev. 2462, which concerns, in part, test data on models of tapered wings with inclined ribs; and AMR 6, Rev. 3726, which concerns a two-cell rectangular wing with inclined ribs. N. C. Costakos, USA

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 3840, 3918, 4036)

3993. McLemore, H. C., and Cannon, M. D., Aerodynamic investigation of a four-blade propeller operating through an angle-of-attack range from 0° to 180°, *NACA TN* 3228, 62 pp., June 1954.

An investigation of the aerodynamic characteristics of a four-blade rigid 5.33-ft-diam propeller has been conducted for blade angles from 0° to 67.5°, a range of advance ratio from 0 to 6.2, and a maximum tip speed corresponding to a Mach number of 0.62. The investigation includes a preliminary exploration of vertical descent and a comparison with theory of the rate of change of the normal-force coefficient with angle of attack and of the aerodynamic characteristics of the propeller at zero angle of attack.

The static thrust results indicate that the blade angle for the maximum figure of merit is slightly greater than 8°. The blade angle for maximum efficiency for forward flight at zero angle of attack is approximately 60°.

The theoretical method used for calculating the rate of change of the normal-force coefficients with angle of attack, normally applied to propellers, does not adequately predict the experimentally determined results for angles of attack greater than 15°. For the blade angles investigated, the strip-analysis theory using available two-dimensional airfoil data adequately predicted the variation of the thrust and power coefficients and efficiency with advantage ratio for an angle of attack of 0°.

From authors' summary by E. Petersohn, Sweden

3994. Iwasaki, M., The experimental and theoretical investigations of windmills, *Rep. Res. Inst. appl. Mech.* **2**, 8, 181–229, Dec. 1953.

A series of tests on 2-, 3-, 4-, and 6-blade windmills over a wide range of blade angles and values of $\Omega R/V$ are reported. The results are compared in some cases with theoretical values, calculated on the basis of Goldstein's vortex theory for the airscrew. Reasonable agreement was obtained. Experimental results could not be obtained for certain ranges of $\Omega R/V$ and small values of blade angle, relative to the plane of rotation. This effect was most marked for 4-blade windmills. The power for all windmills was found to increase as the blade angles were decreased, although the power was found to decrease again for blade angles below 20° for the 6-blade windmill only. No explanation for these phenomena are given.

Results are also given for the windmill working inside a duct of length equal to one third of its diameter. Increased power output was obtained due to the reduction of tip effect. The greatest increase was about 30% above the output of the isolated windmill. Again the experimental results are compared with theory. In this case the additional induced velocity due to the interference of the helicoidal vortex sheets with the cylindrical boundary, assumed of infinite length, is calculated from a solution due to Takeyama [*J. Japan Soc. appl. Mech.* **3**, no. 13, Jan. 1950].

Frequent reference is made to a paper by Sanuki [*Pap. Meteor. Geophys.* **1**, no. 2–4, 279–290, Dec. 1950] in which large power increases were found for windmills operating inside ducts. The increases, it is stated, were due to (a) acceleration of flow through duct and (b) reduction of tip effect.   G. M. Lilley, England

3995. Acosta, A. J., An experimental and theoretical investigation of two-dimensional centrifugal-pump impellers, *Trans. ASME* **76**, 5, 749–763, July 1954.

An experimental and theoretical investigation on a series of two-dimensional centrifugal-pump impellers has been made in an effort to determine the usefulness of potential theory for the description of the flow. Computed values of the developed head and pressure distribution on the vane surfaces are compared with measurements on two-, four-, and six-vaned logarithmic spiral impellers. The agreement between the observed and predicted quantities is reasonably good for operating points where the influence of the inlet turn on the internal flow is least. The discrepancies which occur at other flow rates are attributed to real fluid effects which are observed in the impeller passages.
From author's summary

Reviewer believes that this paper, covering one of the three elements of a pump, will be of value to designers of fluid machines. Similar investigations for the whole of the pump will ultimately be required for completeness.

H. H. Anderson, Scotland

3996. Hiebel, G., Optimum power and efficiency partition of steps in intercooled compression of gas turbine plants (in German), *Motortech. Z.* **14**, 12, 351–353, Dec. 1953.

Pressure partition of intercooled compressors can be arranged for maximum power or maximum efficiency of the plant. Author gives formulas for optimum power and efficiency partition and shows by a numerical example that efficiency, power, temperature, and pressure ratios in both cases are essentially different.

Optimum number of steps requires that the last step provides an essential increment of efficiency or power and shall be run with favorable pressure ratio. This demand can be fulfilled with the help of the given formulas and diagrams.

H. Krüger, Germany

3997. Takashima, Y., Studies on liquid-jet gas pumps, *J. sci. Res. Inst. Tokyo* **46**, 230–246, Dec. 1952.

Paper represents another of many efforts which have been made to establish satisfactory method of designing jet pumps, or ejectors. Approach is mostly experimental, with some theoretical calculations for comparison. Experiments covered range of shapes, areas, and working conditions, with supplementary two-dimensional visual-flow studies. Recommendations for best proportions are given, also empirical equation for determining best working pressures. Conclusion is reached that good performance depends largely on intimate mixture of water and gas and that this can best be obtained by using primary (water) nozzle with several discharge openings in parallel rather than conventional single central opening. Paper adds to accumulation of experimental data available on this type of pump and should be of value to designers.   C. W. Smith, USA

3998. Wisniowski, H. U., and Winterbottom, H., Investigation of scavenging in small two-stroke cycle engines, *Nat. Res. Counc. Canad. mech. Engng.* ME-207, 23 pp., July 1953.

The apparatus was built to investigate the scavenging efficiency of two-stroke cycle engines. Water was used instead of air as the working medium, applying the principle of flow similitude. The method developed for measuring the scavenging efficiency involved the photometric determination of the amount of scavenging fluid retained in the cylinder. Several systems of scavenging were investigated, as applied to the N.R.C. semi-diesel marine engine.

The results are discussed and conclusions drawn.
From authors' summary

3999. Hinton, C., Nuclear reactors and power production, *Engineer, Lond.* **197**, 5119, 5120; 357–360, 374–377, Mar. 1954.

Flow and Flight Test Techniques

(See also Revs. 3840, 3935, 3971, 3983, 3987, 4013, 4025, 4056)

4000. Grey, J., and Liu, F. F., Methods of flow measurement, *J. Amer. Rocket Soc.* **23**, 3, 133–140, May–June 1953.

A review of modern methods of flow measurement.
C. L. Coldren, USA

4001. Thibessard, G., Elastic deformation of flow measurement orifices (in French), *Rev. univ. Min.* (9) **10**, 2, 38–45, Feb. 1954.

4002. Pope, A., Wind tunnel testing, 2nd ed., New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1954, xv + 511 pp. $8.50.

The research worker or engineer on being initiated into the realm of aerodynamic testing immediately becomes aware of the lack of definitive textbooks on the subject. In recent years this undesirable situation has been alleviated considerably by the publication of two excellent volumes: "Wind-tunnel testing," by Pope (1947) and "Wind-tunnel technique," by Pankhurst and Holder (1952) [see AMR **6**, Rev. 2614].

Since its first appearance in 1947, "Wind-tunnel testing" by Pope has achieved due recognition among students and engineers engaged in the design of wind tunnels and the testing of aircraft components and models at subsonic speeds. In the present (second) edition the material has been revised and enlarged to include topics on helicopter rotors, nonaeronautical uses of the wind tunnel, and high-speed aerodynamic testing. The net re-

sult is a much improved and a more topical text. (Several minor misprints were noted, and the value for the mean-free-path at a 100-mile altitude should read about 10 feet instead of 1 mile.)

The book contains the following 12 chapters: 1. The wind tunnel; 2. Wind-tunnel design; 3. Instrumentation and calibration of the test section; 4. Model force, moment and pressure measurements; 5. Testing procedure; 6. Wind-tunnel-boundary corrections; 7. The use of wind-tunnel data; 8. Small wind tunnels; 9. Nonaeronautical use of the wind tunnel; 10. Rotor testing; 11. Nearsonic and transonic testing; 12. Supersonic-wind-tunnel testing.

The most informative and thorough chapters are those dealing with subsonic flow. The treatment of supersonic wind-tunnel design and testing is rather sketchy. The descriptive materials of slip flow and free molecule flow (encountered in high-speed, high-altitude flight) is much too brief to leave the reader with any fundamental concepts, let alone testing requirements. No mention at all is made of the recent pioneer experimental work in this field by the NACA and University of California in their low-density wind tunnels.

The above remarks should not detract from the value of this book, since it becomes practically an impossible task for one author to give a comprehensive account of wind-tunnel design and testing for the continuum, transitional, and free-molecule flow regimes. The need for a definitive work on high-speed (low density) wind-tunnel techniques has yet to be fulfilled. The reviewer would like to recommend this book to personnel engaged in the field of aerodynamic research and testing.

I. I. Glass, Canada

4003. Wyker [Wijker], H., Charts for the estimation of the permissible humidity in supersonic wind tunnels, "Mémoires sur la mécanique des fluides," *Publ. sci. tech. Min. Air, Paris,* 427–443, 1954.

Author gives a clear summary of results by Lukasiewicz (1947), Head (1949), and Oswatitsch (1941). He derives charts for the degree of drying needed to avoid condensation and for the humidity permissible if a condenstion shock is allowed of given strength (pressure rise). Also an approximate treatment is suggested for an extended region of condensation.

R. C. Pankhurst, England

4004. Lukasiewicz, J., and Royle, J. K., Effects of air humidity in supersonic wind tunnels, *Aero. Res. Counc. Lond. Rep. Mem.* 2563, 35 pp., June 1948, published 1953.

The available theoretical and experimental information on condensation of water vapor in the supersonic flow of air is reviewed and the influence of condensation on operation of supersonic tunnels is considered.

The mechanism of condensation in supersonic flow is of molecular nature and does not depend on the presence of solid condensation nuclei in the air. As estimated by Oswatitsch and confirmed by experimental results, the condensation in supersonic flow of air is primarily a function of the adiabatic supercooling $\Delta T_{k\ to\ ad}$ which determines the conditions at which the condensation shock occurs. For medium-sized supersonic tunnels (say 1-ft-sq working section) the adiabatic supercooling is of the order of 50 C.

For most test purposes it is essential to eliminate the detrimental effects of condensation on flow distribution in the tunnel working section. The usual method is to use highly dried air, and the question of the required dryness is considered. Other methods, which do not rely on the dryness of air, are discussed. It is shown that, by increasing stagnation temperature, condensation can be avoided usually only at Mach numbers smaller

than 1.5. Alternatively, condensation can be eliminated from the tunnel nozzle by pre-expansion in an auxiliary nozzle, as verified experimentally.

From authors' summary

4005. Salter, C., Miles, C. J. W., and Lee, Miss H. M., Tests on a swept-back wing and body in the compressed air tunnel, *Aero. Res. Counc. Lond. Rep. Mem.* 2738, 15 pp., May 1950, published 1953.

The model consisted of a sweptback wing of symmetrical section and a long cylindrical body. The aspect ratio was 3.29, the taper ratio 2.75, the sweep of the quarter-chord line 4.25°, the maximum thickness/chord ratio at the root 8.6% and at the tip 10%. It has been tested over a range of Reynolds numbers of 0.5×10^6 to 13×10^6 and results are given to lift, drag, and pitching moment for angles of incidence up to 30°.

From authors' summary

4006. Erdmann, S. F., A new simple interferometer for obtaining quantitatively evaluable flow patterns, *NACA TM* 1363, 62 pp., Nov. 1953.

Paper discusses procedure for obtaining interferograms of variable density flows by means of optical equipment no more elaborate than found in conventional schlieren systems. Object field is considered as an aperture whose diffraction pattern is refocused (either by second lense of collimator or by spherical mirror in the coincidence method) in source image plane. Camera focused on object plane would—in view of size of object fields generally examined—produce faithful photographic image if nothing more were done. This recombination by interference is prevented by tampering with diffraction image. Three possibilities are described: (a) blocking out the zero-order diffraction center (dark-field effect); (b) intercepting the zero-order light by a phase disk, combined with partial absorption if desired (phase-contrast effect); (c) strong absorption of entire remaining field other than diffraction center (field-absorption method). Latter method is recommended for application to compressible-flow analysis because appropriate displacement of field-absorbing diaphragm with respect to diffraction center produces in interferogram the effect as if object field were superimposed on a field of constant density gradient, fringe density increasing with the asbolute value of the latter which, in turn, is determined by the size of the displacement. This facilitates quantitative evaluation as is well known from Mach-Zehnder interferograms, where same effect is achieved by appropriate tilting of beam-splitting plates out of perfectly parallel alignment.

Economy of equipment and ease of adjustment highly recommend the technique for student experiments and laboratory research. Main disadvantages in comparison with four-plate (Mach-Zehnder) interferometer are: (a) low effective utilization of light furnished by source; (b) dependence of fringe pattern on geometric shape of object field complicating proper interpretation; (c) the fact that theory of fringe formation on which quantitative evaluation must be based is not as good an approximation to the detailed physical mechanism involved.

F. J. Weyl, USA

4007. Steen, D., and Casey, D., Theory of the manometer accelerometer, *Rev. sci. Instrum.* 24, 11, 1021–1028, Nov. 1953.

Authors establish equations of motion, including derivation of coefficients, for the departures from equal heights of the liquid levels in U- and ring-shaped tubes subjected to accelerations in the plane of their vertical arms. Results are given as second-order differential equations of motion of the liquid surface, with the coefficients explicitly stated, but the configurations and dimensions which produce these coefficients are not stated. It is

stated that examples of such accelerometers were tested and that "the equation which defined a manometer design was found to agree with the experimental result," but no experimental data are given. Reviewer considers the presentation to be unnecessarily obscure, the obscurity being increased by careless proof-reading and incomplete nomenclature.   M. Mayers, USA

4008. Murphy, S. J., and Connock, S. H. G., Design of a rate-of-rotation recorder, *Nat. aero. Establ. Canad.* LR-68, 34 pp., July 1953.

Report describes a recorder of the continuous trace type designed to record simultaneously the rates of rotation of an airplane about three mutually perpendicular aces. It includes a brief review of some possible methods of measuring rates of rotation and also a theoretical study of the behavior of such recording devices when the parameter to be recorded has a frequency of the same order as that of the recording elements. Results of laboratory dynamic tests are given. It is concluded that in its more sensitive condition the recorder is suitable for measuring varying rates of rotation, the frequencies of which are not in excess of two cycles per second.   From authors' summary

Thermodynamics

(See also Revs. 3927, 3996, 4003, 4034, 4039, 4040)

4009. Schmidt, E., Introduction to technical thermodynamics and to the fundamentals of chemical thermodynamics [Einführung in die technische Thermodynamik und in die Grundlagen der chemischen Thermodynamik], 5th ed., Berlin, Springer-Verlag, 1953, xvi + 520 pp., 244 figs., 69 tables. DM 30.

This treatise is one of the most popular books on thermodynamics in Germany, written for the needs and benefit of students and mechanical engineers. It covers a wide field, emphasizes the importance of the second law of thermodynamics, and deals with a variety of applications of thermodynamics to all types of engines ranging from the steam engine to the most modern types of propulsion and rockets. In addition, the fundamentals of heat transfer, of gas-vapor mixtures, of chemical thermodynamics, and of combustion are treated to some extent. To force this material into a clearly written textbook of some 500 pages is an achievement in itself. The new edition differs only by a few corrections from its predecessor.   W. Gumz, Germany

4010. Metropolis, N., Rosenbluth, Arianna W., Rosenbluth, M. N., and Teller, Augusta H., Equation of state calculations by fast computing machines, *J. chem. Phys.* 21, 6, 1087–1092, June 1953.

Calculations of the equation of state of high density gases from statistical mechanics usually involve cumbersome integrals. An approximate evaluation is shown possible by use of a modified Monte Carlo method of random sampling. A two-dimensional rigid sphere model is used to illustrate and results are compared with those obtained from the free volume and four virial equations of state. The correlation is good over a broad density range not handled by either reference method. The technique can be extended to more complex molecular models.
          N. A. Hall, USA

4011. Malmquist, L., A vapor pressure equation for an extremely wide temperature range (in Swedish), *Kyltekn. Tidskr.* 1, 3, 38–42, June 1954.

A vapor-pressure equation is proposed with high accuracy in an extremely wide temperature range. The deviation from

measurements is $\pm 1.0\%$ for water in liquid state and within the experimental error from ice point to -50 C. The vapor-pressure derivative deviates from tabulated values with $\pm 1.8\%$. The equation involves a logarithmic singularity at the critical point, which seems to be very accurate for many substances. The constants of the equation have physical meaning: The critical temperature; the critical pressure; and two limit constants, one according to the behavior of the substance at the critical point and one to the behavior at absolute zero temperature. In the solid-state range the melting entropy constitutes a fifth constant.
          From author's summary by C. E. Lenngren, Sweden

4012. International Civil Aviation Organization, Montreal, Canada, and Langley Aeronautical Laboratory, Manual of the ICAO standard atmosphere calculations by the NACA, *NACA TN* 3182, 132 pp., May 1954.

This manual presents tabular values of the "Standard Atmosphere" adopted by the ICAO. The values were calculated by the NACA and the new manual supersedes the tables and figures of *NACA Rep.* 218 on the Standard Atmosphere. The latest values of the fundamental physical constants were used in the calculation of the properties of this atmosphere.

The tabular values of the properties of the ICAO Standard Atmosphere require somewhat more than 100 pages of text in fine type. The altitude ranges from 16,500 ft below sea level to 65,800 ft above sea level. Four tables present properties such as temperature, pressure, density, speed of sound, etc., in metric units, and similarly, four additional tables present the same properties in English units.

This manual will be widely used by all who deal with the properties of the atmosphere. Its format makes these tables readily available for computation with automatic computing machines.   J. Kaye, USA

4013. Lundberg, S., A method for approximate determination of viscosity-pressure-temperature relationships for oils. Results from an investigation of compressibility and viscosity, *J. Inst. Petr.* 40, 364, 104–115, Apr. 1954.

Correlating method gives compressibility and viscosity as function of temperature over range 15 C to 130 C, pressures from 1 to 1200 kg/cm². Light and heavy fuel oils, including Swedish shale and California residual, lubricating oil, and peanut oil were studied. Method requires determining viscosity-temperature relationship at atmospheric pressure, then obtaining two viscosity determinations at elevated pressures and corresponding unique elevated temperatures. The plot of viscosity (vertical logarithmic scale) versus pressure (horizontal arithmetic scale) results in straight lines having common origin. Intermediate lines can be plotted using common origin as one point and temperature viscosity values at atmospheric pressure as other points. Unique temperatures and corresponding pressures at which to measure viscosities are on smooth curve (arithmetic scale) having approximate values of 20 C at 1 kg/cm², 32 C at 100 kg/cm², 46 C at 200, 60 C at 300, 78 C at 400, 105 C at 500 kg/cm².

Author observed delay in return of density to initial value on release of pressure—phenomenon appeared to be associated with oil rather than with apparatus.   D. Aronson, USA

4014. Mackie, A. G., Expansion of a finite one-dimensional gas cloud into a vacuum, *Proc. roy. Soc. Edinburgh* (A) 64, part I, no. 4, 57–70, 1954.

An investigation is made of the motion of a one-dimensional finite gas cloud which is initially at rest and is allowed to expand into a vacuum in both directions. The density of the gas at rest is assumed to rise steadily and continuously from zero at the boundaries to a maximum in the interior of the cloud.

If the subsequent motion is continuous, it is completely specified by analytical solutions in seven different regions of the $x - t$ plane joined together along characteristics. The motion of one of the boundaries is discussed, and conditions found for it to have (1) an initial stationary period or (2) a final constant velocity of advance into the vacuum. The gas streams in both directions from a dividing point at zero velocity. This point ultimately tends to the midpoint of the initial distribution.

The possible breakdown of the continuity of the motion is discussed, and a condition on the initial density distribution is found for shock-free flow to be maintained.

<div style="text-align: right">From author's summary</div>

4015. McDonald, J. E., Homogeneous nucleation of super-cooled water drops, *J. Meteor.* **10,** 6, 416–433, Dec. 1953.

The experimentally observed crystallization of supercooled water near −40 C is examined in terms of the theory of homogeneous nucleation. The thermodynamic and molecular-kinetic nature of the nucleation process is outlined to show why supercooling in natural clouds can occur so frequently. Past efforts to explain the −40 C transition are examined critically and are found to contain a number of significant errors. Because the theoretical nucleation rates are extremely sensitive to the numerical value of the specific surface free energy of a water-ice interface, particular attention is devoted to the refinement of previous estimates of this parameter. It is shown that both Krastanow's and Mason's estimates are inaccurate and that, in the latter's approach, neglect of the distortion energy of the surface layer of ice led to a marked underestimate of the nucleation efficiency, which was concealed by the effects of several counteracting errors. Difficulties lying in the way of a direct calculation of the distortion energy for ice are examined and found to be very serious. A crude correction for distortion effects leads to a theoretically predicted temperature of −26 C for the threshold of spontaneous nucleation of drops of cloud-particle size. It is concluded that although this result lies well above the experimentally observed range of transition temperatures, it is close enough to that range (considering the inherent difficulty of assessing the effect of distortion) to strengthen the belief that the −40 C transition is due to homogeneous nucleation.

<div style="text-align: right">From author's summary</div>

Heat and Mass Transfer

(See also Revs. 3805, 3829, 3914, 3962, 4009, 4088, 4089, 4093, 4094)

4016. Ruh, E., Improved method of measuring thermal conductivity of dense ceramics, *J. Amer. ceram. Soc.* **37,** 5, 224–228, May 1954.

An instrument has been developed to measure the thermal conductivity of dense ceramic materials over the temperature range 20 to 200 C. A cylindrical ceramic specimen $1/2$ in. in diam by $1/2$ in. long is used in the instrument. Pressures lower than 1μ of mercury are used to reduce heat losses and to permit rapid attainment of steady-state conditions.

<div style="text-align: right">From author's summary</div>

4017. Blanc, A., Application of Thévenin's theorem to heat-transfer problems (in French), *C. R. Acad. Sci. Paris* **235,** 2, 136–138, July 1952.

Temperature fields in which heat sources and thermal conductors with and without thermal lag are arranged can often be put in approximate analogy with electrical networks consisting of several current sources, resistors, and capacitors. In case of linear relations, i.e., no dependency of material constants on temperature, solutions are derived in the form of matrixes.

<div style="text-align: right">Margot Herbeck, Germany</div>

4018. Krishnan, K. S., and Jain, S. C., Temperature distribution in an electrically heated filament, *Nature* **173,** 4409, 820–821, May 1954.

4019. Manson, S. V., Temperatures, thermal stress, and shock in heat-generating plates of constant conductivity and of conductivity that varies linearly with temperature, *NACA TN* 2988, 62 pp., July 1953.

Working formulas are presented for the steady-state temperatures and thermal stress in heat-generating infinite plates of constant conductivity and of conductivity that decreases linearly with temperature as the temperature increases, for the case in which the heat is generated uniformly throughout the plate thickness and both faces of the plate are equally cooled. A criterion is indicated for determining the surface cooling conditions under which the thermal shocks at the surface and midplane will be smaller than, equal to, or greater than the steady-state thermal stresses. Dimensionless parameters governing transient temperatures and thermal stresses in materials of linearly varying conductivity are derived. A numerical technique for solving the transient-state equations is detailed.

<div style="text-align: right">From author's summary by F. C. Hooper, Canada</div>

4020. Pappas, C. C., Measurement of heat transfer in the turbulent boundary layer on a flat plate in supersonic flow and comparison with skin-friction results, *NACA TN* 3222, 32 pp., June 1954.

Local heat-transfer rates on the surface of a heated flat plate at zero incidence to an air stream flowing at Mach numbers of 1.69 and 2.27 are presented. The Reynolds number range for both Mach numbers was 1 million to 10 million. Surface temperatures were maintained near recovery temperature. It was found that the variation of heat transfer with Mach number was in agreement with previously reported variations of directly measured skin friction with Mach number on unheated bodies. The variation with Mach number of the average skin-friction coefficient, as determined from impact-pressure surveys, was in agreement with that from other momentum loss measurements but differed from the variation obtained from directly measured skin friction as reported by others.

<div style="text-align: right">From author's summary by Y. S. Touloukian, USA</div>

4021. Marris, A. W., The momentum and vorticity transfer theories of turbulent heat transfer, *Canad. J. Phys.* **32,** 6, 419–429, June 1954.

Author's work on the estimation of radial temperature distribution across the turbulent core of gas flowing through a tube was extended further from the viewpoint of transfer analogies. The posturation of transferring mechanism, either by momentum or by vorticity, leads, respectively, to different basic equation and gives different boundary thickness or the limit of integration. For the particular case of Prandtl number equal to the ratio of eddy diffusivities for vorticity and heat, the expressions giving the temperature distribution in terms of Nusselt number Nu, Fanning friction factor f, Reynolds number Re, and radial distances, and those giving Nuf in terms of Re, f, and radial distance were worked out for each case. Comparing the values of Nu and Nuf calculated at different Re, author concludes that the smaller heat-transfer coefficients obtained on the vorticity anal-

ogy result from the larger distance of penetration into the turbulent region.

This work may be regarded as an outstanding contribution to the theories of turbulent heat transfer.　I. Sawai, Japan

4022. Hellman, S. K., Habetler, G., and Babrov, H., Use of numerical analysis in transient solution of two-dimensional heat-transfer problem with natural and forced convection, ASME Semi-Ann. Meet., Pittsburgh, Pa., June 1954. Pap. 54—SA-53, 20 pp.

Study arises in connection with determination of thermal stress in a nuclear reactor that occurs during transient stage. Temperature distribution is required for complicated areas containing sources of heat and through which liquid metal flows. Finite difference techniques are applied to equations for solution on a digital computer. Stability and truncation errors are studied. No numerical results are presented.　Y. Luke, USA

4023. Beighley, C. M., and Dean, L. E., Study of heat transfer to JP-4 jet fuel, Jet Propulsion, 24, 3, 180–186, May-June 1954.

The use of rocket fuels as coolants before burning them is frequently proposed. For this reason, the heat-transfer properties of two JP-4 hydrocarbon rocket fuels were studied during flow at 3 to 40 fps, 30 to 500 psia, and up to 10 Btu/sec/sq in. in a cylindrical annulus about 0.075 in. wide and heated at its $^3/_{16}$-in. ID. Nonboiling heat-transfer coefficients h with 13-microin. RMS wall roughness showed no effect of viscosity variation and fell 7% below the Sieder and Tate equation and 12% below the Dittus and Boelter equation. Sandblasting the heated tube to 60 microin. increased h about 50%. L/D_e from 6.7 to 27 had no effect. In nucleate boiling h was proportional to Δt and increased with pressure and velocity. Burn-out occurred when the ratio of maximum or burn-out to nonboiling heat flux at the same conditions equaled $(11,080/PG)^{1/2.54}$, PG being in lb/in.^{1}/sec. Above the critical pressure, near 550 psia, nonboiling changed directly into film boiling. Above 25 fps and 300 psia, the tube did not burn out on going into film boiling. Coking occurred above 800 F.　C. F. Bonilla, USA

4024. Giulianini, A., Convective diffusion (in Italian), Termotecnica 8, 5, 303–307, May 1954.

Indicates application of dimensionless groups of mass and heat transfer for interchanging actual values of one coefficient of a diffusional process to that of another. Method has long been applied by engineers, but article is of value for establishing relationships in formal manner.　J. M. DallaValle, USA

4025. Reese, B. A., and Graham, R. W., Experimental investigation of heat-transfer and fluid-friction characteristics of white fuming nitric acid, NACA TN 3181, 46 pp., May 1954.

Experiments have been conducted to determine the heat-transfer and fluid-friction characteristics of white fuming nitric acid over a wide range of conditions. A satisfactory equation for relating the Fanning friction coefficient with heat transfer and the isothermal friction coefficient measured at the same Reynolds number is presented. An equation is also presented for correlating the heat-transfer results. Some preliminary results are presented for the regime of forced convection with nucleate boiling.　From authors' summary

4026. Silver, A. H., On heat transfer in a compressible laminar boundary layer, J. aero. Sci. 21, 5, 352–353, May 1954.

Author extends approximations of Tifford and Lighthill to include effects of compressibility.　J. A. Lewis, USA

4027. Zaat, J. A., A one-parameter method for the calculation of the temperature profile of laminar incompressible boundary layer flow with a pressure gradient, Nat. LuchtLab. Amsterdam Rap. F. 127, 34 pp., Mar. 1954.

Paper describes theory for computing temperature distribution in laminar boundary layers based on a new approximation to the shape of the temperature profile, the von Kármán momentum equation, and the integrated heat equation. The new approximation is based on the asymptotic behavior of the temperature distribution as derived from the momentum and heat equations. Only the general theory is presented, without examples.

H. L. Dryden, USA

4028. Yih, C.-S., Temperature distribution in laminar stagnation-point flow with axisymmetry, J. aero. Sci. 21, 1, 37–42, Jan. 1954.

An exact solution of the Navier-Stokes equation in the neighborhood of a stagnation point in axisymmetric flow is applied to investigate the temperature distribution in such a flow for various axisymmetric temperature conditions on the boundary. Approximate solutions are found for the following two cases: (1) Diffusion from a point source of heat at the stagnation point; (2) diffusion from the boundary when the increment of the boundary temperature over the ambient temperature varies as an arbitrary power of the radial distance from the axis of symmetry.

The temperature rise due to viscous dissipation is included in the treatment, and the thermal effect of pressure change in gases is discussed. The solutions obtained are presented graphically as functions of the Prandtl number.　L. Landweber, USA

4029. Merk, H. J., and Prins, J. A., Thermal convection in laminar boundary layers. I, II, III, Appl. sci. Res. (A) 4, 1, 3; 11–24, 195–206, 207–222, 1953, 1954.

Authors investigate first conditions under which the free thermal convection will have boundary-layer character, finding that the Grashof number should be greater than 10^4 provided that the Prandtl number is great. In part 1, cases are treated (both for plane and axisymmetrical flows) having similarity properties with respect to their thermal and velocity profiles, which imposes conditions on the shape of the body. Mathematically, the problem then reduces to a system of ordinary differential equations, solved by a method suggested by Saunders. In parts 2 and 3 the similarity condition is abandoned and a sort of Pohlhausen method used (original as well as refined Squire-Eckert method). Results are compared with an exact numerical solution of Schuh for a flat plate (agreement being satisfactory) and with experimental results due to E. Schmidt for horizontal cylinders, the agreement being less satisfactory for local Nusselt number distributions.

A. von Baranoff, France

4030. Schenk, J., and Dumoré, J. M., Heat transfer in laminar flow through cylindrical tubes, Appl. sci. Res. (A) 4, 1, 39–51, 1953.

The Nusselt modulus for transfer of heat from the fluid through a constant, uniform thermal resistance to a constant temperature heat sink is computed for three finite values of the thermal resistance. The results obtained are stated to allow of interpolation for any value of resistance. The special case of zero thermal resistance corresponds to the system treated by Graetz. A simple method for calculating the total Nu for arbitrary cases is suggested. Some mathematical properties of the differential equations and the functions occurring in this problem and in the analogous problem of heat transfer for flow between parallel plates are summarized.　F. E. Romie, USA

4031. Berry, V. J., Jr., Non-uniform heat transfer to fluids flowing in conduits, *Appl. sci. Res.* (A) **4**, 1, 61–75, 1953.

The general theory of the temperature distribution in a fluid flowing in a heated conduit is discussed. Equations are derived for the temperature distribution throughout the fluid stream, and an expression is presented for the Nusselt modulus as a function of downstream position. A definite criterion is proposed for estimation of the thermal entry length. In addition, it is shown that the asymptotic value of the Nusselt modulus depends not only upon the geometry and the hydrodynamics of the system but also upon the temperature boundary conditions imposed. A simple procedure is given for computation of the heat-transfer coefficient when velocity and effective thermometric conductivity distributions are available. Both round pipes and parallel wall conduits are considered.

From author's summary by F. E. Romie, USA

4032. Shaposhnikov, I. G., Theory of convective phenomena in a binary mixture (in Russian), *Prikl. Mat. Mekh.* **17**, 5, 604–606, Sept./Oct. 1953.

Author develops and discusses basic equations for weak gravity-temperature and gravity-concentration media in a binary mixture.

Mechanical equilibrium of a mixture, whose temperature and concentration vary at different points, is not possible in all cases where these two quantities are distributed. If their distribution is such that mechanical equilibrium is not possible, then there is a moving media which is accompanied, generally speaking, with transfer of heat and mass component of the mixture. This means that a convection phenomenon of both gravitational temperature and gravitational concentration takes place.

The developed equations for studying such phenomena are limited to cases where the medium (when convection takes place) does not differ materially from a balanced state. Use is made of hydrodynamic equations for binary mixtures.

From Molotov's summary by W. Green, USA

4033. Eckert, E. R. G., Diaguila, A. J., and Curren, A. N. Experiments on mixed-free-and-forced-convective heat transfer, connected with turbulent flow through a short tube, *NACA TN* 2974, 59 pp., July 1953.

In a vertical tube with a length-to-diameter ratio equal to 5, heat-transfer experiments have been carried out. By heating the walls of the tube and conducting air in either upward or downward direction through the tube, it was possible to investigate the heat transfer with forced-flow parallel and opposite to the direction of the buoyancy forces. The Grashof number could be varied between approximately 10^9 and 10^{13} and the Reynolds number varied from 36×10^3 to 377×10^3.

Since the transition from forced-to-free-convection is continuous, the determination of the limits of the mixed-flow region requires some arbitrary definition. So the mixed-flow regime has been defined as that part in which the influence of both the Reynolds and Grashof number of the heat-transfer coefficient is larger than 10%.

Probably a less arbitrary definition may be obtained when a number of the form Gr/Re^2 is introduced. Certain critical values of this group may define the limits of the mixed-flow regime.

A remarkable result is the fact that the heat-transfer coefficients found in the counterflow are up to two times larger than the higher of the values calculated for pure forced or free convection flow, whereas in the parallel flow these coefficients are somewhat smaller than the calculated values.

A survey is given of the mixed-flow regime in a Re, Gr-diagram wherein the ranges of Re and Gr are extended with the aid of the work of Watzinger and Johnson for the transition region and the work of Martinelli and Boelter for the laminar region.

J. A. Businger, Holland

4034. Johnson, E. F., Molecular transport properties of fluids, *Indust. Engng. Chem.* **46**, 5, 889–893, May 1954.

A survey of developments during 1953. Ed.

4035. Beckwith, I. E., The effect of dissociation in the stagnation region of a blunt-nosed body, *J. aero. Sci.* **20**, 9, 645–646, Sept. 1953.

Author proposes an approximate method for the calculation of the heat transfer on an arbitrary two-dimensional body in the presence of equilibrium dissociation, using for the velocity and for the stagnation enthalpy profiles fourth-degree polynomials, and with the dissociation data represented by a fifth-degree polynomial of the enthalpy. The analytical discussion for the case of stagnation flow shows that equilibrium dissociation has a negligible effect on the heat transfer for wall temperatures below the dissociation temperature. K. Pohlhausen, USA

4036. Shepard, C. E., and Warshawsky, I., Electrical techniques for time lag compensation of thermocouples used in jet engine gas temperature measurements, *Instruments* **26**, 11, 1725–1730, Nov. 1953.

The characteristics and limitations of the resistance-capacitance type and of the transformer type of time-lag compensators are discussed for thermocouples. Recommended circuits are described for turbine outlet and for compressor temperatures to supplement hot-wire anemometer data. Time-lag compensation is necessary when large-wire thermocouples are used for longer life and ease of installation. A. O. Flinner, USA

4037. Seban, R. A., Remarks on film condensation with turbulent flow, *Trans. ASME* **76**, 2, 299–302, Feb. 1954.

Paper applies the Prandtl-von Kármán fluid-flow heat-transfer analogy to turbulent film condensation. Nusselt's assumptions concerning momentum and energy balances are retained and the Prandtl-Nikuradse velocity distribution for flow in smooth pipes is assumed to apply in the condensate layer. Equations and graphs are presented for the over-all heat-transfer coefficient as a function of Prandtl and Reynolds numbers and for Reynolds number as a function of Prandtl number and a generalized wall length. Reviewer believes development satisfactorily represents turbulent film condensation for Prandtl numbers below unity. For larger Prandtl numbers, neglect of kinematic viscosity when thermal diffusivity is not neglected leads to inaccurate prediction of turbulent layer heat-transfer resistance. Fortunately, this resistance is relatively unimportant for large Prandtl numbers. However, development could be refined by including kinematic viscosity throughout. This would require a change in velocity profile near the film surface, to prevent negative values of eddy diffusivity. Further refinements which could be readily introduced and are probably worth while are: (1) the use of a turbulent Prandtl number to relate eddy diffusivity and eddy viscosity, and (2) elimination of assumption that the sublayer and buffer-layer thicknesses are much less than the film thickness. The only equation error found is in Eq. (11), left side of which should be divided by kinematic viscosity. Finally, reviewer feels comparison with literature data could have been shown more readily by use of a graph to augment percentage errors quoted.

R. R. Hughes, USA

4038. Guthmann, V. K., Status of immersion temperature measurements (in German), *Stahl u. Eisen* **73**, 26, 1693–1705, Dec. 1953.

4039. Kawata, S., and Omori, Y., An investigation of thermo-couple psychrometer, I, *J. phys. Soc. Japan*, **8,** 6, 768–775, Nov.-Dec. 1953.

Properties of thermocouple psychrometers consisting of fine wires of constantan and manganin were studied. Various effects such as conduction of heat through wires, transfer of heat through air between dry and wet junctions, ventilation, and lag of indication were examined experimentally. Conditions were given by which these effects could be reduced or substantially eliminated in psychrometric measurements. The response of the wet junction of the thermocouple psychrometer was compared for various wire diameters and was compared with the response of the wet bulb of a mercury-in-glass thermometer. Authors expressed the opinion that the effect of radiation on the wet junction could be reduced sufficiently by a slight amount of ventilation. This latter point was to be discussed further in part 2 of their investigation.   D. M. Vestal, Jr., USA

Combustion

(See also Revs. 3895, 4023)

THE FOLLOWING PAPERS (REVS. 4040–4047) WERE PUBLISHED IN Fourth Symp. (International) on Combustion, 1953: Baltimore, Md., Williams & Wilkins. $7.

4040. von Kármán, T., and Millán, G., Thermal theory of a laminar flame front near a cold wall, 173–177.

Cold walls influence flame propagation in tubes, especially quenching. Authors treat problem of wall influence on basis of thermal theory of combustion, starting from general equations for two-dimensional steady flow with viscosity, heat conduction, and chemical reaction, simplified for deflagration at almost constant pressure. Flame front is assumed stationary at $x = 0$ (x is direction of gas flow parallel to wall, y normal to wall) [cf. von Kármán and Millán, AMR **6**, Rev. 2909]. First approximation: flame front infinitely thin, $T = T_0$ (initial temperature) for all x and $y = 0$, heat conduction in y-direction only. Problem analog to boundary-layer problems, isotherms are parabolas $y^2 \sim x$. Second approximation: above solution assumed for x, y large compared with characteristic length l ($= \lambda/\rho_0 u_0 C_p$, λ thermal conductivity, ρ_0, u_0 density and flow velocity in x-direction for $x = -\infty$, C_p specific heat) measuring heat penetration into unburnt gas. Within specified region x, $y > 0$ numerical solution by means of Kármán's integral equation of theory of boundary layers.

Authors have stated problem very clearly, as well as limitations of results and feasible improvements. Soundness of results is seen from calculated dead space near wall which, though smaller than observed, is proportional to values observed by Kaskan.   W. Jost, Germany

4041. Richardson, J. M., The existence and stability of simple, one-dimensional, steady-state combustion waves, 182–189.

An equation for one-dimensional steady-state flame propagation based on a simple diffusion model is stated. The limit of existence in the presence and absence of a flame holder is examined. Limits of flammability and the question of stability are discussed.

The method of solution is to interchange the role of the dependent and independent variables. Author finds the steady-state solution to be stable.   Marjorie W. Evans, USA

4042. Dugger, G. L., and Graab, D. D., Flame velocities of hydrocarbon-oxygen-nitrogen mixtures, 302–310.

Burning velocity data were obtained for iso-octane, propane,

and ethylene in various oxygen-nitrogen mixtures at 311 and 422 K to obtain a better understanding of the importance of reaction kinetics in flame propagation. The Bunsen-burner technique was employed at atmospheric pressure and the burning velocity was calculated from schlieren photographs of the flame by a total area method. The maximum burning velocities were linear with respect to the mole fraction of oxygen in the oxygen-nitrogen mixture at 311 and 422 K. These data were taken from curves of burning velocity as a function of equivalence ratio for a series of oxygen to oxygen-nitrogen ratios at the two temperatures. Although the original data are not reported, it is noted that such curves exhibited a burning-velocity maximum at an equivalence ratio between 1.0 and 1.1 for isooctane and propane, and propane, and between 1.1 and 1.2 for ethylene. Empirical equations are presented for the maximum burning velocity as a function of initial temperature and oxygen concentration.

The results are compared with theoretical values obtained by the thermal theory of Semenov and the diffusion theory of Tanford and Pease, with average deviations of 5 to 15%. Linear correlations between maximum burning velocity and active particle concentrations were not found. The reviewer believes that comparisons of theory and experiment of this type must be made with great caution because the temperature variation of many of the terms is not sufficiently well known.   H. F. Calcote, USA

4043. Leason, D. B., The effect of gaseous additions on the burning velocity of propane-air mixtures, 369–375.

Burning velocity was determined by measuring the surface area of the separated inner cone of the flame on the water-cooled burner tip. The measurements of the effects on propane-air mixtures of the addition of iso-octane, benzene, acetone, methyl ethyl, ketone, carbon monoxide, diethyl ether, oxygen, hydrogen, and nitrogen, show that the burning velocity is not solely dependent on the flame temperature; the comparative merits of thermal or diffusion theory are, however, not discussed in this report. An almost straight line relationship exists between burning velocity and the parameter ($6.5\ P_h + P_0 + P_{OH}$) for a wide range of fuels and mixture strengths, and there seems little likelihood of materially increasing the burning velocity of fuels by the inclusion of small quantity of another combustible. The variation of burning velocity is dependent on the concentration of active species in the zone of maximum flame temperature and on their relative diffusion rate. Experimental results are presented in curves.   P. Bielkowicz, USA

4044. Karlovitz, B., Denniston, D. W., Jr., Knapschaefer, D. H., and Wells, F. E., Studies on turbulent flames. A. Flame propagation across velocity gradients. B. Turbulence measurement in flames, 613–620.

In part A the laminar propagation of a flame across a velocity gradient such as might exist in a boundary layer is studied theoretically. Authors conclude that laminar flame speed can be seriously reduced by effect of velocity gradient if flow velocity increases considerably within the preparatory zone of the flame; and that if flame speed is reduced to a small fraction of the normal value, propagation of the flame may be entirely interrupted by small velocity fluctuations. Reviewer notes questionable assumptions that density is constant in preparatory zone and that ratio of ignition excess temperature to temperature gradient at ignition is identical for stretched and unstretched flames.

In part B are described two new experimental techniques for measurement of turbulent fluctuations in turbulent flames. The first method, applicable to measurements within the flame brush, is based on experimental fact that the ionization density is several times higher in immediate vicinity of the instantaneous combustion wave than in the hot combustion gas; a small wire

probe, immersed in the flame brush of a turbulent flame and kept at a negative potential against the flame plasma so that it collects positive ions, receives a much stronger current when the instantaneous flame front comes into contact with the probe than when the probe is enveloped only by the hot combustion gas. The second method, applicable to measurements in the hot-gas flow immediately behind the flame, is based on the variation of the probe current with flow velocity in a uniformly ionized gas.

A. H. Shapiro, USA

4045. Hottel, H. C., Williams, G. C., and Levine, R. S., The influence of isotropic turbulence on flame propagation, 636–644.

Authors compare combustion in a laminar jet and in the same jet with isotropic turbulence of measured intensity and scale introduced by screens. They find the apparent increase in burning velocity can be explained by assuming the local flame velocity remains at the laminar value while the area is increased by protuberances whose heights are proportional to the intensity of the turbulence and diameter to the scale.   W. Squire, USA

4046. Scurlock, A. C, and Grover, J. H., Propagation of turbulent flames, 645–658.

A theoretical study of the effect of turbulence on flame propagation is made, assuming the local burning velocity is the laminar flame speed and the area is increased. The increased area is computed by writing an approximate differential equation based on a linear superposition of the effects of eddy diffusion, flame propagation, and flame-generated turbulence.

The calculated results show some similarity to experimental results (Wohl, Shore, and Rosenberg), and some of the deviations may be attributed to the simplifying assumptions.

W. Squire, USA

4047. Charyk, J. V., Glassman, I., and John, R. R., The mixing and burning of two concentric fluid streams, 886–893.

Experimental results are reported for simulated ram-rocket propulsion system in which jet exhaust of liquid oxygen-gasoline rocket motor is allowed to mix and burn with a ducted air stream surrounding the rocket, the mixture ratio of the rocket being adjusted so that products of combustion are rich in combustible gases. Mixing and burning took place in pipe 6 ft long and 8 in. in diam.

In the system investigated, the fluid dynamic effects, rather than chemical kinetic effects, are controlling. For such systems the investigation demonstrates the validity of a one-dimensional analysis for the complete process of mixing and burning and presents data correlating the longitudinal pressure distribution during mixing and burning.   A. H. Shapiro, USA

4048. Whittle, J., Effect of vaporization rate on the weak combustion limit of liquid fuel sprays, Fuel 33, 2, 192–194, Apr. 1954.

This author has missed the true point of his research. Particle size is the key to the mass-surface ratio. The surface absorbs sensible heat to bring the particle to boiling point. Large particles have unfavorable mass-surface ratios. Low heat density therefore requires very small particle size to convert the liquid droplets to burnable vapor.

The key to this research lies in consideration of not only particle size but also heat density in the vaporization zone and means for maintenance of higher heat densities than are now common to the art.

Reviewer's research indicates markedly reduced critical nature for particle size in heat levels suitable for proper vaporization. Vaporization should be stable at any condition of aeration to provide stable burning. Reviewer has proved this can be done.

R. D. Reed, USA

4049. Moore, N. P. W., and Simonson, J. R., Ignition of methane-air mixtures by rapid compression, Nature 173, 4403, 543–544, Mar. 1954.

4050. Putnam, A. A., Effect of boundary layer thickness on flame stability, Fuel 33, 3, 355–363, July 1954.

The boundary layers on axial-rod flame holders were removed by a suction groove, at various distances from the flame-holding end of the rod. This permitted new boundary layers of controlled thicknesses to be formed. The blow-off data from tests on these rod flame holders have been examined and compared with the results of other investigators. Blow-off data for other shapes of flame holders, but of the same size, were also considered. It was concluded that, in a nonturbulent stream, the boundary-layer thickness has no effect on flame holding. In a turbulent stream there can be a penetration of the turbulence through a thin boundary layer and a consequent decrease in stability limits. If the boundary layer itself is turbulent, the stability of the flame will be greatly reduced. Finally, for a constant size of flame holder, the angle at which the flame leaves the holder has a pronounced effect on the lean-side stability limit.

From author's summary by A. Levy, USA

4051. Kurz, P. F., Importance of flame configuration in stability experiments, Fuel 33, 3, 291–294, July 1954.

Data are presented which show that flames having different configurations in a vortex burner may not be compared to one another. Application of the additivity rule for fuel mixtures no longer holds when the fuels are dissimilar. Examples are given for hydrogen-ethylene mixtures and for hydrogen-hydrogen-sulfide mixtures.   A. Levy, USA

4052. Kurz, P. F., Vortex burner—A useful tool for studying the flame stability of gaseous fuels and fuel mixtures, Rev. sci. Instrum. 25, 5, 418–421, May 1954.

A unique burner is described which is capable of maintaining stable combustion with gaseous fuel-oxidant mixtures having widely varying burning velocities. Rapid mixing of fuel and oxidant is obtained in a high velocity vortex. Flashback and blow-off can be avoided.

Reviewer believes the title is somewhat misleading. Unfortunately, the flow pattern does not lend itself to simple analytical treatment. Therefore, any attempt to obtain fundamental combustion characteristics with this burner would be difficult, if not impossible. Observed results on flame stability will have meaning only in association with a particular burner of particular dimensions operating under particular conditions. The mere fact of ability to provide reproducible and measurable observations does not endow a device with usefulness for scientific research.   J. B. Fenn, USA

4053. Rosen, J. B., Theory of laminar flame stability. I. Analytic stability condition, J. chem. Phys. 22, 4, 733–742, Apr. 1954.

It has been shown by earlier workers in this field that the solution of the flame equations is essentially an eigenvalue problem for the determination of burning velocity. For simple systems, steady-state solutions will exist for all fuel-oxidant ratios and no indication of any discontinuity in the solutions is obtained which would point to the existence of either inflammability or detonation limits. Present author is of the opinion that this apparent contradiction is due to the steady-state solution not necessarily being a stable solution. The effect on the steady-state solution of a simple case by a perturbation in the form of an instantaneous heat source or sink is examined and the existence of stability

limits shown. An analytic expression for stability of the solutions to the flame equations is obtained in terms of several parameters, such as activation energy and reaction rate. It is suggested by the author that the existence of these stability limits affords an explanation of limits of inflammability.

A. H. Howland, England

4054. Rosen, J. B., Theory of laminar flame stability. II. General numerical method and application to typical system, *J. chem. Phys.* **22,** 4, 743–748, Apr. 1954.

In a previous paper (see preceding review) author examined the problem of the stability of an idealized laminar flame in the presence of a perturbation by an instantaneous point source release of heat. In the present paper, the steady-state solutions for a three-component system are considered and, in addition to temperature perturbation, the effects of concentration and mass-flow perturbations are examined. Because of the complicated nature of the present problem, the flame equations must be solved numerically and a general method is described which is suitable for automatic programming on a high-speed digital computer. The method is applied to two specific cases of a typical flame-propagating medium and comparison is made with the approximate treatment given in part 1 [ibid.] of this paper. It would appear that the approximate treatment, in which only the effects of temperature perturbation are considered, is quite good.

A. H. Howland, England

4055. Rosen, J. B., Combustion wave stability and flammability limits, *J. chem. Phys.* **22,** 4, 750–751, Apr. 1954.

This is a continuation of work described in the two preceding reviews, where it is shown that an essentially thermal instability of the steady-state solutions to a laminar combustion wave can occur. The author has now obtained a simplified stability condition which permits the examination of the stability as a function of the fundamental physical parameters. As suggested in his earlier papers, it would appear that the stability limits indicated by the thermal perturbation of the steady-state solutions of the flame equations have their physical counterpart in inflammability limits.

The treatment does not appear to be in a sufficiently advanced stage to permit direct comparison with experimental data on inflammability limits, as this will require the introduction of more detailed kinetic data. The author suggests, however, that the simplified model is suitable to explore the general outlines of flame-stability behavior. A. H. Howland, England

4056. Penner, S. S., Spectroscopic studies of premixed laminar flames, Colloquium, AGARD, Cambridge Univ., Dec. 7–11, 1953: "Selected combustion problems, fundamentals and aeronautical applications," London, Butterworths Scientific Publications, Ltd., 1954, viii + 534 pp., 144–166.

A critical review is presented of the results obtained by spectroscopic observations on flames. The objective of the survey is to examine the status, promise, and deficiencies of combustion spectroscopy in its relation to (a) elucidation of the mechanism of combustion and (b) the solution of technical combustion problems. Since important spectroscopic studies have been carried out on low-pressure flames, a discussion of the probable effects of pressure on laminar flame propagation is also included.

From author's summary

4057. Green, L., Jr., Erosive burning of some composite solid propellants, *Jet Propulsion* **24,** 1, 9–15, 26, Jan.-Feb. 1954.

Earlier work on this subject is first discussed briefly, where it is indicated that the erosive burning of a solid propellant, i.e., the dependence of its burning rate on the velocity of gas flow parallel to the burning surface, may be correlated in terms of an erosion ratio expressed as a function of velocity. As the exact form of this function does not appear to be known, the present work was undertaken to provide experimental data for this purpose. The standard partial-burning technique was used in which the propellant grain is extinguished after burning for a recorded interval of time and the amounts of propellant burned off at various points along the grain determined. The experimental data were best correlated in terms of a reduced mass velocity G/G^*, where G is the cross-sectional average mass velocity in the flow channel and G^* is the critical value of G required to produce a Mach number 1 in the channel; but owing to the limited scope of the investigation, the proposed correlation was not conclusively established. In addition, in agreement with other workers, it was found that the erosive effect was greater in slow than in fast-burning propellants, and the existence of a threshold velocity for erosion below which variation in gas velocity had very little effect on the burning rate was also noted. Author is of the opinion that this latter effect is only apparent and is due to the failure of the one-dimensional flow treatment of the results for conditions near the fore end of the grain, where a well-defined boundary layer is not established. A. H. Howland, England

4058. Geckler, R. D., The mechanism of combustion of solid propellants, Colloquium, AGARD, Cambridge Univ., Dec. 7–11, 1953, "Selected combustion problems, fundamentals and aeronautical applications," London, Butterworths Scientific Publications, Ltd., 1954, viii + 534 pp., 289–339.

The normal linear burning rate of solid propellants increases with (1) an increase in the pressure of the gases in contact with the burning surface, (2) an increase in the temperature of the solid propellant, and (3) an increase in the velocity of the combustion gases parallel to the burning surface. Experimental data on these phenomena are summarized for both colloidal and composite propellants. An attempt is then made to show the relationship between the concepts and methods developed for the study of deflagration in gases and the theories of solid-propellant combustion. The present status of the theoretical study of solid-propellant combustion is reviewed, with particular attention being given to the theories of O. K. Rice and B. L. Crawford, Jr. The values of various kinetic parameters deduced by the application of their theories to experimental burning-rate data are compared with values obtained in other ways. A summary of experimental and theoretical information on unstable combustion is also given. The distinctive feature of this phenomenon is an abnormally high burning rate that accompanies high-frequency pressure oscillations in rocket combustion chambers. It is concluded that the theoretical understanding of the combustion of solid propellants is not sufficient to be of much practical aid to the propellant chemist seeking formulations with improved properties. From author's summary

Author has provided a valuable summary of unclassified information on solid-propellant combustion. A few factors influencing burning properties were not discussed, however. Propellants with high flame temperatures may show large, irregular increases in burning rate (worm-holing) as a result of radiant heat transfer to propellant layers slightly below the burning surface [W. H. Avery, "Radiation effects in propellant burning," *J. phys. coll. Chem.* **54,** 917–928, 1950]. This effect may require addition of darkening agents, such as carbon black or nigrosine dye, to those propellants which are otherwise translucent. The burning rate also has been found to vary with position in the grain, being greater in the center of the web than at the surface [R. N. Wimpress, AMR **4,** Rev. 462]. This effect has been observed in both

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colloidal and composite propellants. Extruded double-base propellants of the JP-JPN type also show a greater burning rate parallel to the direction of extrusion than perpendicular to it [Wimpress, loc. cit.].   L. Green, USA

4059. Hubbard, W. N., Katz, C., and Waddington, G., A rotating combustion bomb for precision calorimetry. Heats of combustion of some sulfur-containing compounds, *J. phys. Chem.* 58, 2, 142–152, Feb. 1954.

4060. Durin, M., On a phenomenon of oscillatory combustion in internal-combustion engines (in French), *C. R. Acad. Sci. Paris* 238, 13, 1380–1382, Mar. 1954.

4061. Eatwell, H. J., and Withers, J. G., The significance of laboratory octane numbers in relation to road anti-knock performance, *Instn. mech. Engrs., Auto. Div.,* part III, 111–120, 1951–1952.

Engine conditions which affect knock are discussed, and the fact that all fuels do not react equally to these conditions are dealt with in some detail. Laboratory and road knock-rating methods are described, and the results of tests on British and American cars are used to demonstrate a relationship between laboratory and road antiknock ratings. It is shown that the road antiknock performance of fuels is directly affected by their "sensitivity," to a greater or less degree depending on engine "severity." From authors' summary by M. Rand, Canada

4062. Davis, J. D., Factors affecting the utilization of anti-knock quality in automobile engines, *Instn. Mech. Engrs., Auto. Div.,* part III, 100–110, 1951–1952.

This interim report contains a wealth of graphs showing the octane requirement vs. speed for different types of engines. Curves of general trend are shown (although individual points are scattered widely), but the student of combustion cannot obtain a precise picture. A mere description of an engine as "Type X, side valves, CR. N:1" does not convey much to the uninitiated reader. Reviewer finds that identification by brand names (particularly for engines showing favorable performance) certainly will enable any student to obtain a more detailed knowledge. Under such circumstances, those working on similar research can derive great benefit from this work, but as presented it will be of value only to those knowing the engines used.
                                                      M. Rand, Canada

Acoustics

4063. Kemp, N. H., On the pressure field of a uniformly moving concentrated force, *J. acoust. Soc. Amer.* 26, 3, 450–451, May 1954.

A theoretical derivation is given which reduces the differential equation for the moving force by well-known techniques and then uses a method due to H. Lamb. Attention is called to a sign error in previous works. The final result is useful in propeller noise theory, in studies of an oscillating thin airfoil in compressible subsonic flow, and in studies of a finite oscillating wing.
                                                      R. C. Binder, USA

4064. Chambré, P. L., Speed of a plane wave in a gross mixture, *J. acoust. Soc. Amer.* 26, 3, 329–331, May 1954.

Author presents two mathematical derivations of the expression for the speed of propagation of a plane compressional wave in a suspension or emulsion of one substance in another (small air

bubbles or kaolin or xylene in water). He verifies the relation proposed by A. B. Wood ["A textbook of sound," 1930, 327–328]. No assumption is necessary concerning the compressibility of the mixture in terms of the compressibilities of the components, nor does the disturbance have to be of small amplitude.
                                                      R. Heller, USA

4065. Peake, W. H., and Thurston, E. G., The lowest resonant frequency of a water-loaded circular plate, *J. acoust. Soc. Amer.* 26, 2, 166–168, Mar. 1954.

Authors use Rayleigh's method to obtain fundamental frequency of circular clamped and simply supported plates loaded on one side by fluid reaction. Analysis provides a convenient approximate approach, valid when plate diameter is small compared to wave length. Assumptions as to the pressure field in the fluid are the same as in H. Lamb's analysis [*Proc. roy. Soc. Lond.* (A) 98, 205, 1920]; in particular, in deriving the fluid reactance, compressibility of fluid is ignored (this is strictly valid for extremely small frequencies only).

Reviewer would like to draw attention to exact analysis by M. Lax [title source, 16, 5–13, 1944] for a clamped plate. Lax shows that effect of fluid reaction is to couple modes of plate.
                                                      M. C. Junger, USA

4066. Lippert, W. K. R., A method of measuring discontinuity effects in ducts, *Acustica* 4, 2, 307–312, 1954.

The method described in this paper consists of terminating the duct beyond its discontinuity with a nonreflecting load and exploring the sound field on both sides of the discontinuity with a movable microphone. From these measurements the transmission and reflection are determined and discussed.
                                                      H. L. Oestreicher, USA

4067. Lippert, W. K. R., The measurement of sound reflection and transmission at right-angled bends in rectangular tubes, *Acustica* 4, 2, 313–319, 1954.

The method described in the foregoing review is applied to the title problem. It is shown that good agreement exists with the zero-order approximation of the theoretical solution given by J. W. Miles in 1947.   H. L. Oestreicher, USA

4068. Hafemeister, R. N., The ultrasonic testing of forging ingots, *ASTM Bull.* no. 197, 52–55, Apr. 1954.

Heavy ingots are tested ultrasonically prior to forging (0.5 mc, Sperry reflectoscope, heavy-bodied cylinder oil as couplant, preparation of the location to be tested by grinding an area of 4 in. in diameter). It is shown by three examples that the forging process can be modified properly when the location of secondary pipes, loose or porous centers, etc., are known. Some screen diagrams of typical faults in forging ingots are included.
                                                      O. Ruediger, Germany

4069. Lassiter, L. W., and Hubbard, H. H., The near noise field of static jets and some model studies of devices for noise reduction, *NACA TN* 3187, 38 pp., July 1954.

Experimental results are given for pressure fluctuations near the jet from a turbojet engine of 3825-lb thrust; from small model nozzles and orifices, operated choked and unchoked, cold and hot (to 1600 F); and from these models supplied with air bleeder orifices and wire-mesh-type noise-reduction devices. Near-field sound pressures from the engine were strongest below 150 cps. At stations two nozzle diameters from jet boundary, pressure fluctuations maximized at 12 to 15 diam downstream. On cold unchoked model jets, near-field fluctuation pressures

varied about as jet velocity to second power. This exponent increases with radial distance from nozzle. Wire screening (8 mesh) athwart flow $1/3$ diam downstream reduced far-field low frequencies markedly but increased some high frequency components. Screech of hot and cold choked jets was also decreased by screens and bleeder air orifices; no thrust reduction data are given. Temperature of hot unchoked jets affects noise only through jet velocity.   V. Salmon, USA

4070. Nyborg, W. L., Self-maintained oscillations of the jet in a jet-edge system. I, *J. acoust. Soc. Amer.* **26,** 2, 174–182, Mar. 1954.

The dynamical theory is proposed that each particle of a low-velocity jet, issuing from a slit orifice and moving toward a symmetrically placed obstacle, is acted on by transverse forces of a hydrodynamic nature. This supposition leads quickly to a nonlinear integral equation of motion. The assumption, not here justified by author, of simple forms for the unknown functions involved in the integral equation leads to solutions in the case of steady periodic motions which partially agree with empirical formulas previously used. Better quantitative results would possibly be obtained by a more accurate forecast of these unknowns. Finally, a comparison is made with hydrodynamical theories based on a supposed tendency of the jet to form a von Kármán vortex street.   G. Power, England

4071. Jack, W. A., Noise control in industrial areas—principles and practice, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-55, 12 pp.

Paper presents a well-written discussion of basic quantities and equations for sound analysis and shows the effects of structural procedures in the reduction of noise. A number of fundamental industrial examples are cited, with adequate calculations and tables.

Reviewer believes this paper contains excellent background material for engineers interested in the techniques for noise reduction, without involving redesign of the machines.
                                                            J. J. Ryan, USA

4072. Parolini, G., Some aspects of sound attenuation in buildings (in Italian), *G. Gen. civ.* **91,** 10, 589–607, Oct. 1953.

Paper gives a general account of the acoustic insulation of floors in building construction. The test floor is separated from its support by a continuous layer of acoustic insulating material. As far as low frequencies are concerned, author considers the problem as a system of one degree of freedom with viscous damping and elastic support. At frequencies greater than 1 kc he considers the problem of one of sound transmission through a composite layer, which acts as a low-pass filter. The results of some experimental tests are described; these show a considerable reduction in sound level and qualitative agreement with the theory proposed.   J. M. Jackson, Scotland

4073. Kobrynski, M., and Liénard, P., Method of study and design of light insulating acoustic materials (in French), *Rech. aéro.* no. 35, 43–47, Sept.-Oct. 1953.

The reason for this study was the necessity of insulating air passengers from flight noise produced by air sound or by vibration of the structure transmitted by the fuselage walls. Samples of wall material suitable for sound absorption are chosen and examined for air sound in an acoustic device, carefully avoiding every experimental error. The difference between incident and transmitted sound pressure is measured in dependence on frequency in the range from 50 to 10,000 cps. Measurement is made by only one process and presented on the screen of an oscillograph.

Some samples were found to have the desired property. They transmit less than expected by the law of mass, owing to the internal friction and to the combination of material. Rules for sound insulation are concluded from these results and from other known facts.   P.-P. Heusinger, Germany

Soil Mechanics, Seepage

(See also Revs. 3898, 3925)

4074. Shield, R. T., Stress and velocity fields in soil mechanics, *J. Math. Phys.* **33,** 2, 144–156, July 1954.

This paper is concerned with stress and velocity fields in soil materials. Solutions are presented which are based on the assumption that a soil is a plastic material in which slip or yielding occurs when the stresses satisfy the Coulomb formula [Terzaghi, "Theoretical soil mechanics," John Wiley and Sons, 1948, p. 22].

Particular emphasis is given to discontinuities in stress fields for cohesive soils. Detailed solutions of stress distributions are worked out for various shaped wedges.   J. Aronofsky, USA

4075. Casagrande, A., and Wilson, S. D., Effects of stress history on the strength of clays, *Harvard Soil Mech. Ser.* no. 43, 71 pp., June 1953.

This important paper presents results of drained and consolidated undrained triaxial tests on four clays, carried out under various conditions of loading, in order to evaluate the effects of preconsolidation, rate of loading, sample disturbance, and other details of the stress history on the strength of clays. Some fruitful ideas concerning effective stress-strain relations, rather similar in content to Skempton's ψ theory, are introduced, which serve to unify to some extent the experimental findings. The controversial nature of the subject is emphasized by the authors' claim that their experiments support the view that the inclination of slip planes in compression tests is $(\pi/4 + \phi/2)$, where ϕ is angle of drained shearing resistance, and by the fact that the term *cohesion* is entirely avoided.   R. E. Gibson, England

4076. Jumikis, A. R., Suction force in soils upon freezing, *Proc. Amer. Soc. civ. Engrs.* **80,** Separ. no. 445, 14 pp., June 1954.

A formula is derived relating frost heave to suction head and rate of upward flow of water from a water table. Apparatus for their measurement is described.   E. S. Barber, USA

4077. Plantema, G., Soil pressure measurements during loading tests on a runway, *Proc. Third Inter. Conf. Soil Mech. Foundation Engng.,* Aug. 16–27, 1953, vol. I, 289–298.

Paper describes the results of experimental measurements made on a specially constructed test section in order to compare several types of runway constructions. Sand was placed over a natural subsoil by vibration to a depth of 1 m and loaded by a ballasted traverse moved on rails. Pressure cells were placed at two depths; settlements were measured at the surface using dial gages and at the bottom of the sand layer using cones which transmitted vertical motion to the surface by means of rods enclosed in tubes.

Results are presented graphically, appearing to be consistent, and agree well with distribution calculated from the Boussinesq equation, although stratum was not homogeneous, consisting of two distinct layers. A layer of furnace slag and a layer of crushed stone were also added on top of the sand and caused pressures materially to decrease even for same over-all depth. Hardening of the slag layer with time caused a definitely more favorable stress distribution (pressure in sand decreased about 20% when

tested one year later). Analyses showed continuing settlements with time were due to action of subsoil, not compression in sand.

Aside from direct value of results, reviewer believes paper is of significance in presenting additional near full-scale test results to correlate with soil theories.   G. J. Tauxe, USA

4078. Khanna, P. L., Varghese, P. C., and Hoon, R. C., **Bearing pressure and penetration tests on typical soil strata in the region of the Hirakud Dam project,** *Proc. Third. Inter. Conf. Soil Mech. Foundation Engng.*, Aug. 16-27, 1953, vol. I, 246-252.

Article reports on a most interesting field study conducted to determine relations between field load tests and the penetration resistance of cone penetrometers and spoon samplers. The correlation curves obtained are being employed at the Hirakud Project to estimate allowable bearing pressures for foundations. Triaxial compression test data have also been studied, but no reliable correlations are reported. Apparently, consolidation tests have not been considered in the study.

J. A. Cheney, USA

4079. Takanaev, R. F., **Features of earth dam construction on soft soils by displacement method** (in Russian), *Gidrotekh. Stroit.* 22, 4, 6-8, Apr. 1953.

Based on experience gained in reconstruction of an earth dam, a formula is given for computation of the stage heights of dam necessary to displace the mud from the base. The formula contains the thickness of the mud layer, the unit weight of the dam, and two parameters depending on the angle of internal friction, corresponding to the actual porosity of the mud. Particular attention is given to the stability of the upstream and downstream toes. Some successful constructions of dams by this method were carried out.   L. Šuklje, Yugoslavia

Micromeritics

(See also Revs. 3922, 3926)

4080. Einstein, H. A., and Chien, N., **Second approximation to the solution of the suspended load theory,** *Univ. Calif. Inst. of Engng. Res. MRD Sediment Series* no. 3, 30 pp., 12 figs., Jan. 1954.

Paper presents several alternate sets of assumptions, all based on the exchange theory of turbulence designed to refine the authors' first approximation of 1950. One of the cases proves mathematically intractable, while the other five show improvement in correlation with the limited available data when compared with the original theory. The particular case which assumes that mixing length and velocity fluctuation follow certain probability distributions seems most promising to the authors. Further experimental data are needed to compare the cases critically.   D. F. Gunder, USA

4081. Einstein, H. A., and Chien, N., **Transport of sediment mixtures with large ranges of grain sizes,** *Univ. Calif. Inst. of Engng. Res. MRD Sediment Series* no. 2, 73 pp., June 1953.

Paper extends the experimental work of 1950 by the same authors to the case of more heterogeneous bed loads, including particles of silt size in some cases. Some modification of previous theory parameters is required to cover new cases. Among the conclusions reached are: (1) Segregation by size occurs for heterogeneous bed load, requiring modification of transport parameters. (2) A more general function seems applicable for particles from 0.01-mm to 1-mm diameter. (3) In the case of an aggrading canal the transport can be correlated to the bed deposit in a

manner uniquely defined and easily sampled in the field. (4) The rate of transport is unique for all grains. For a given bed and flow, there is only one rate of transport. (5) Well-graded material deposits at high rates in the form of alternate coarse and fine layers even if the flow conditions remain unchanged. (6) If the bed composition of an aggrading river and its flow at the time of deposition become known, the rate of sediment motion at that time can be roughly estimated. This method is applicable to the "bed material load" as well as to the "wash load."

D. F. Gunder, USA

4082. Vennard, J. K., **Stokes' law confirmed by falling sphere experiment,** *Civ. Engng., N. Y.* 24, 4, p. 58, Apr. 1954.

Geophysics, Meteorology, Oceanography

(See also Revs. 3927, 4012)

4083. Abdullah, A. J., **A proposed mechanism for the development of the eye of a hurricane,** *J. Meteor.* 2, 3, 189-195, June 1954.

Author assumes an immature tropical cyclone is caused by a stationary vortex in the lower layer of a two-layer system. This immature stage is not hydrodynamically stable and develops hydraulic jumps at its most intense region. These jumps are sufficient to destroy the energy and transform the hurricane into its mature stage. A numerical computation gives about five days to destroy the storm in this manner.   W. P. Elliott, USA

4084. Bushby, F. H., and Hinds, M. K., **Computation of tendencies and vertical motion with a two-parameter model of the atmosphere,** *Quart. J. roy. meteor. Soc.* 80, 343, 16-25, Jan. 1954.

The system of partial differential equations given by Sawyer and Bushby (1953) for the rates of change of the 1000-500-mb thickness and the 500-mb contour height has been solved on an electronic computing machine for three synoptic situations; the fields of vertical motion were also computed. The results, described in this paper, show reasonable agreement with actuality. The implied 1000-mb height tendencies also agree quite well with those actually observed.   From authors' summary

4085. MacCready, P. B., Jr., **Structure of atmospheric turbulence,** *J. Meteor.* 10, 6, 434-449, Dec. 1953.

From the theory of isotropic turbulence, especially from Kolmogoroff's similarity hypothesis, simple relationships can be derived for correlation coefficients, power density spectrum, etc., under conditions of isotropic turbulence within a certain range of frequencies. These results have been critically reviewed by the author in the first part of the paper. He then shows that his own measurements of atmospheric turbulence [AMR **7**, Rev. 2709] are in good agreement with these theoretical results, although atmospheric turbulence cannot be regarded as isotropic. Also the range of frequencies, where he gets agreement, is much larger than can be expected.

If this consistancy can be proved by further measurements, the relatively simple conceptions of Kolmogoroff's hypothesis might be applied to many scientific and technical problems, which is discussed briefly.   H. Merbt, Sweden

4086. Weekes, K., **The physical state of the upper atmosphere,** *Quart. J. roy. meteor. Soc.* 80, 343, 2-15, Jan. 1954.

4087. Hislop, G. S., and Davies, D. M., **An investigation of high-altitude clear-air turbulence over Europe using Mosquito aircraft,** *Aero. Res. Counc. Lond. Rep. Mem.* 2737, 39 pp., June 1950, published 1953.

4088. Stern, S. C., and Schwartzmann, F., An infrared detector for measurement of the back radiation from the sky, *J. Meteor.* 2, 2, 121–129, Apr. 1954.

A long-wave radiometer is described in considerable detail. Physical and transmission characteristics of the hemispherical "windows" are presented, and calibration and use of the instrument are discussed. The results of a series of nighttime and daytime measurements of the infrared emissions of the atmosphere are compared with theoretical values obtained from the Elsasser radiation diagram, and satisfactory agreement is found to exist.

From authors' summary

4089. Bunker, A. F., Measurements of the vertical water vapor transport and distribution within unstable atmospheric ground layers and the turbulent mass exchange coefficient, *Pap. phys. Oceanogr. Meteor.* 12, 3, 42 pp., Dec. 1952.

Momentum, heat, smoke, and water vapor are exchanged between the surface layers and higher layers of the atmosphere by identical or analogous processes. Author describes a series of experiments concerning the vertical diffusion of water vapor in air moving offshore over eastern U. S. coastal waters. By repeated airplane soundings, the mass of water transported through various horizontal surfaces is estimated. From this data are computed the coefficients of turbulent mass exchange. The total water-vapor flux for some cases is separated into diffusive transport (due to random eddies) and convective transport (due to organized upward currents). Wide variations in the computed coefficients are shown to exist, only part of the variation being traceable to the stability of the air. Although the basic ideas involved are not new, the reviewer believes that the methods of investigation followed and the careful presentation of results contribute significantly to the little information available on atmospheric diffusion.

F. I. Badgley, USA

4090. East, T. W. R., and Marshall, J. S., Turbulence in clouds as a factor in precipitation, *Quart. J. roy. meteor. Soc.* 80, 343, 26–47, Jan. 1954.

4091. Hinkelmann, K., Numerical weather forecasting using relaxation methods with regard to baroclinic effects, I, II (in German), *Tellus* 5, 3, 4; 251–259, 499–512, Aug., Nov. 1953.

In an important paper published in *Berichten des Deutschen Wetterdienst i. d. US-Zone*, no. 38, 416–428, 1952, author discussed a method for the approximate solution of the quasi-geostrophic equations in an arbitrary baroclinic atmosphere subjected to normal boundary conditions. In this paper, the above method is applied for the *three-dimensional model*, while many writers treating the problem of numerical prediction discussed three-layer model, parameter model, etc. Certain influence functions are computed for the standard atmosphere by means of a relaxation method, where it is assumed that a source exists at one grid point only. The solutions permit the determination of the reaction of the atmosphere to a perturbation and give the clear image for the problem of the propagation of errors in the numerical prediction.

H. Arakawa, Japan

4092. Teweles, S., Jr., A test of the relation between precipitation and synoptic patterns at 200 and 300 millibars, *J. Meteor.* 10, 6, 450–456, Dec. 1953.

4093. Neumann, J., On a relationship between evaporation and evapotranspiration, *Bull. Amer. meteor. Soc.* 34, 10, 454–457, Dec. 1953.

4094. Wexler, R., Reed, R. J., and Honig, J., Atmospheric cooling by melting snow, *Bull. Amer. meteor. Soc.* 35, 2, 48–51, Feb. 1954.

Lubrication; Bearings; Wear

4095. Machlin, E. S., and Yankee, W. R., Friction of clean metals and oxides with special reference to titanium, *J. appl. Phys.* 25, 5, 576–581, May 1954.

Metal-to-metal static friction measurements are made using riders of Al, Ag, Mg, Cu, Cd, Pb, and Zn against freshly cut surfaces of Ti, Fe, and Cu. Comparison is made between friction in air and in deoxidized nitrogen or argon. With the exception of Mg, all of the rider metals were reported to give an increase in friction in the inert atmosphere on one or more of the slider metals. The increase in friction in the inert atmosphere was believed to be due to a decrease in oxide protection. Mg was believed to oxidize even in the inert atmosphere. The influence of the energy of adhesion was demonstrated, particularly in the case of Fe and Ag where it is low and where friction remains low. It is concluded that solid-phase welding accounts for almost the entire static friction for most metal-metal contacts, even when the two metals are mutually insoluble in the solid state. Titanium is believed to weld independently of the atmosphere. It is suggested that a measure of the solid-phase weldability is the quotient of the work of adhesion to the strength of the weaker component.

Reviewer believes this dependence requires additional supporting data. Also, the variations in Ti friction reported as significant appear to require re-examination. V. R. Johnson, USA

4096. Banks, W. H., and Mill, C. C., Some observations on the behaviour of liquids between rotating rollers, *Proc. roy. Soc. Lond. (A)* 223, 1154, 414–419, May 1954.

Closely spaced rotating rollers covered with liquid appear in many industrial processes. The forces and torques on the rolls and the continuity of the liquid film between them are of importance to the design of the machine and the success of the process. The authors present the results of the Navier-Stokes equations for viscous flow applied to this problem. They show that, when rolls rotate in opposite directions, positive pressure exists on the entering film and negative pressures on the diverging side. Formation of vapor pockets (cavitation) occurs when the pressure becomes low enough in the diverging side.

Observation of the occurrence of cavitation was made on transparent cylinders of equal size, closely spaced, and rotating in opposite directions. The independent variables were the separation (2 to 24 μ), the speed (up to 1600 rpm), and the viscosity of the liquid (paraffin oil and castor oil). The speed at which cavitation occurred had a linear relationship with the 3/2 power of the distance between the rollers as predicted by the theory. The authors are to be complimented on the performance of this meaningful experiment. G. H. Sines, USA

4097. Peterson, M. B., and Johnson, R. L., Friction and wear investigation of molybdenum disulfide. II. Effects of contaminants and method of application, *NACA TN* 3111, 19 pp., Mar. 1954.

Lubrication and wear-reduction properties of MoS_2 were investigated for both thick and thin coatings of loose powder and for a bonded coating, also for MoS_2 contaminated with SiO_2, water vapor, and light mineral oil. Steel running surfaces, very carefully cleaned, were loaded at 40 lb and run from 2 to 6 hr. Highly purified MoS_2 in thin films gave a coefficient of friction of 0.025 in dry atmosphere; films bonded with "Epon" gave 0.075; and thick, dry films 0.06 to 0.12. Effect of orientation after "running-in" is clearly demonstrated as a decrease in friction. Running-in atmosphere of 40 to 50% relative humidity increases friction considerably. Contamination with SiO_2 (present in most

commercial grades) increases friction slightly and wear considerably. Light mineral oil added to MoS_2 is shown to give essentially dry atmosphere behavior at 40 to 50% relative humidity; similarly high temperature (300 F) gives nearly dry atmosphere values. Reviewer believes the work is carefully done, giving reliable results and a generally consistent physical picture. Some of the data demonstrate a behavior differing from the general picture which requires additional explanation.

V. R. Johnson, USA

4098. Rabinowicz, E., Solid film lubrication, *Prod. Engng.* 25, 3, 188–192, Mar. 1954.

A timely and informative technical treatment of the subject of boundary lubrication and solid film lubrication. A short and clear treatment of the weld theory of friction is the reader's introduction to the problems of boundary lubrication. The advantages and disadvantages of the various types of solid film lubricants (e.g., inorganic film, such as oxides and phosphates; layer lattice films, such as graphite and molybdenite; soft metal films, such as indium and lead; long-chain organic materials, such as metallic soaps; and solid film synthetics, such as teflon) are discussed in terms of the penetration of the lubricant film and the ratio of the shear strength of the lubricant to that of the contacting materials. A useful table of applications of various types of dispersion-type lubricants is included.

E. Koenigsberg, USA

4099. Lodge, A. S., and Howell, H. G., Friction of an elastic solid, *Proc. phys. Soc. Lond.* (*B*), part 2, 67, 410, 89–97, Feb. 1954.

A study of frictional forces and the coefficient of friction under the assumption that contacting asperities are deformed elastically under load. The empirical relation $F = \alpha R^n$, where F is the frictional force, R the normal reaction, α a friction coefficient, and n a friction index, is assumed. The assumption of elastic deformation leads to expressions for α and n which depend on the geometry of the contacting surfaces. Three contact cases are discussed: (1) Plane surfaces, (2) cylindrical surfaces, and (3) a string round a cylinder. In all cases, the index n is independent of the nature of the contacting materials if shear properties are independent of the load. α, however, differs from the classical coefficient of friction in that, besides being dependent upon the contacting materials, it depends also on the size, shape, distribution, and concentration of the contacting asperities. Further, the exact form of the friction-load relation depends ultimately on the particular experimental method.

E. Koeningsberg, USA

4100. Wright, K. H. R., An investigation of fretting corrosion, *Instn. mech. Engrs. Proc.* (*B*) 1B, 11, 556–563, 1 plate, 1952/1953.

The wear process has been substantiated. The pronounced effect of humidity is shown. Inhibiting fretting by the use of lubricated phosphated surfaces is recommended.

E. F. Macks, USA

Marine Engineering Problems

4101. Hoerner, S. F., The effect of roughness concentration upon the frictional drag, *J. Amer. Soc. nav. Engrs.* 66, 2, 497–503, May 1954.

Author has noted that certain skin-friction coefficients of rough surfaces obtained from trials of various ships and tests of plates painted with ship-bottom paints have exhibited a pronounced decrease with increase of Reynolds number, whereas the findings of Nikuradse and of Prandtl-Schlichting show coefficients of rough surfaces reaching a constant value. He refers to experiments at NACA showing that slope of coefficient curve varies from zero at 100% density of roughness elements to that of the smooth surface at zero density. Author points out that ship hull-surface roughness is considerably less than 100% and such surfaces can approximately be treated as combinations of portions of smooth surfaces and rough portions of varying size of roughness. This was also brought out by Todd [*Trans. Soc. nav. Arch. mar. Engrs.* 59, 315–374, Nov. 1951]. Author derives empirical relationship between slopes of coefficient curves of different densities of roughness against percentage of density ratio and indicates values from various experimenters. He believes that relationship explains discrepancies existing in ship frictional-resistance problems. Author states further experimental work is necessary to firmly establish values and ranges of friction coefficient curve slopes and roughness densities for ship bottoms.

Reviewer concurs that further work is necessary and believes author's conclusions are not entirely justified in view of limited data available. Paper is somewhat brief and difficult to follow.

R. B. Couch, USA

4102. Muckle, W., The buoyancy curve in longitudinal strength calculations, *Shipbuilder* 61, 547, 101–103, Feb. 1954.

4103. Brockmann, W., Stability of damaged boats (in German), *Hansa* 91, 5, 241–244, Jan. 1954.

4104. Some interesting ship and machinery defects, their investigation and cure. A symposium of short papers, *Trans. Inst. mar. Engrs.* 66, 4, 69–89, Apr. 1954.

Symposium contains the following papers: Davis, A. W., Excessive consumption of lubricating oil on Doxford engine; Low, D. W., Problems of a geared diesel propulsion system; Gatewood, A. R., Temporary repair of a cracked diesel engine crankshaft; Gatewood, A. R., Repairs to the fractured cast-iron cylinder of a beam air pump; Gatewood, A. R., Temporary repair of a fractured low-pressure turbine rotor; Ross, H. G., Repair of a low-pressure turbine rotor; Yates, H. G., Thermal straightening of turbine rotors; Falconer, W. H., High-pressure turbine cylinder casting repair; Byrne, E., Turbine journals: machining in place in wake of carbon packing; Hims, H. E. C., An improvised balancing operation; Bunyan, T. W., Some further vibration problems relating to ships and their associated machinery.   Ed.

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